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December 1988
Volume 12 Number 11

Technology Forecast '89

Subject Index Of All 1988 Tech Briefs

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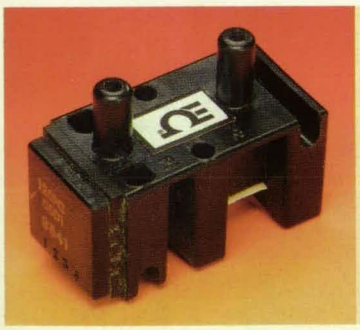

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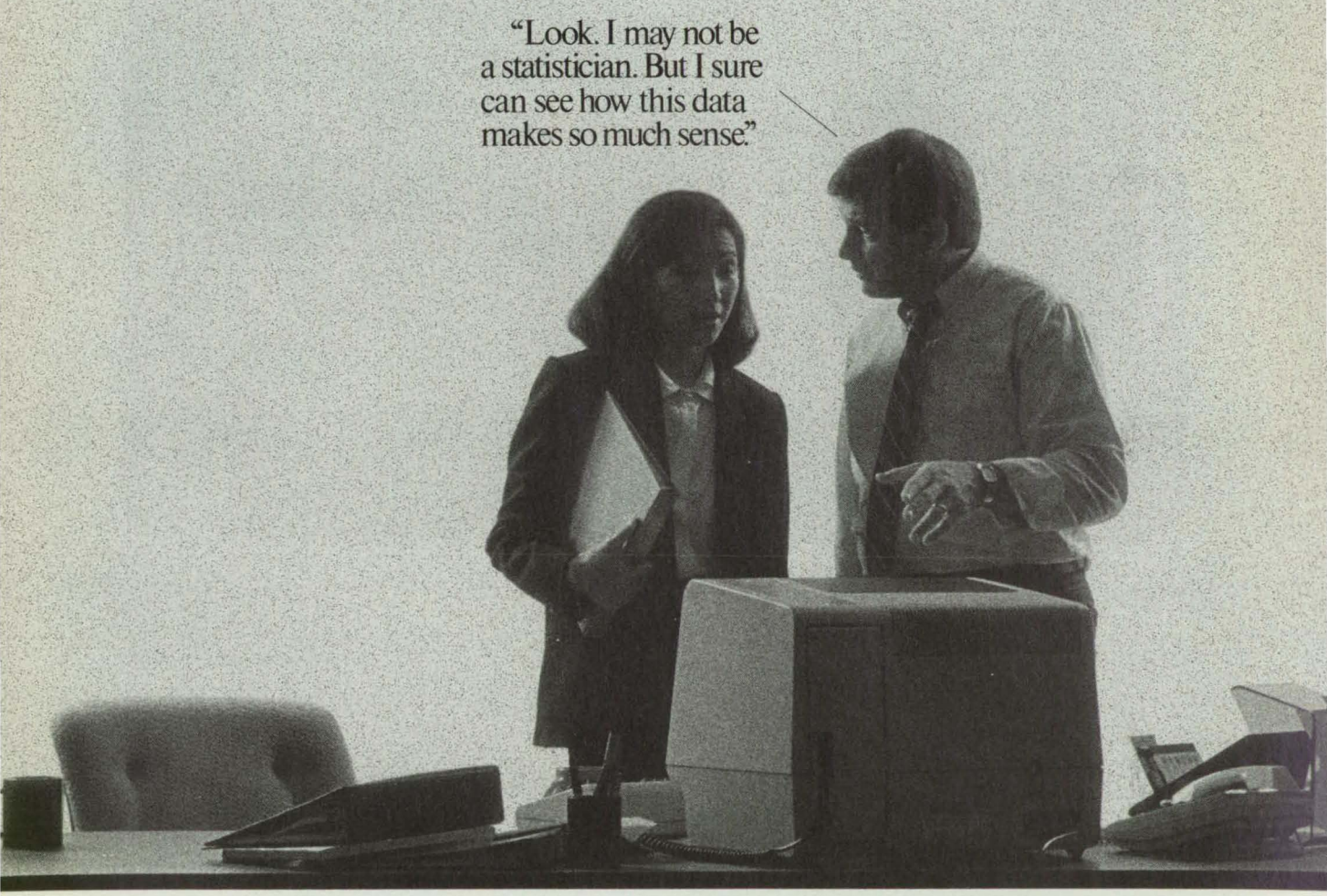

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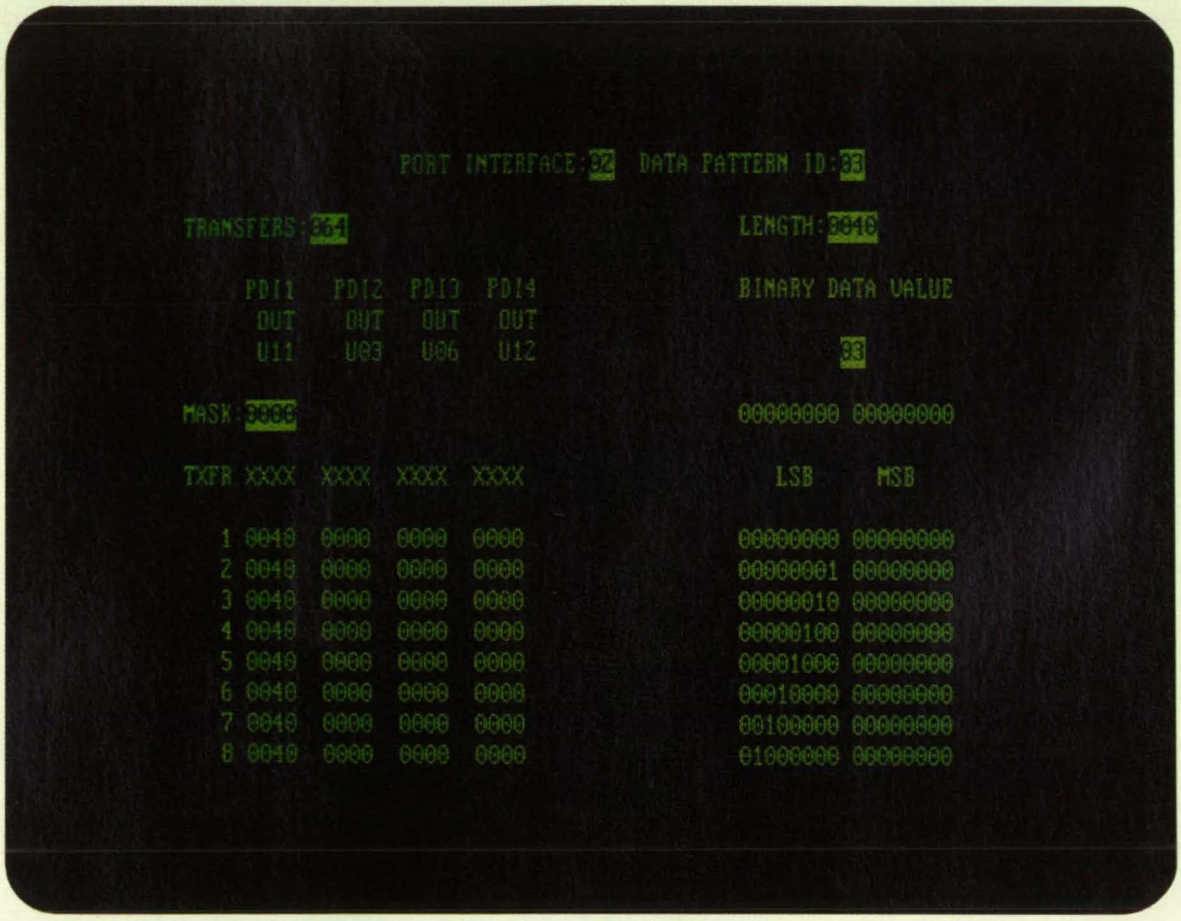

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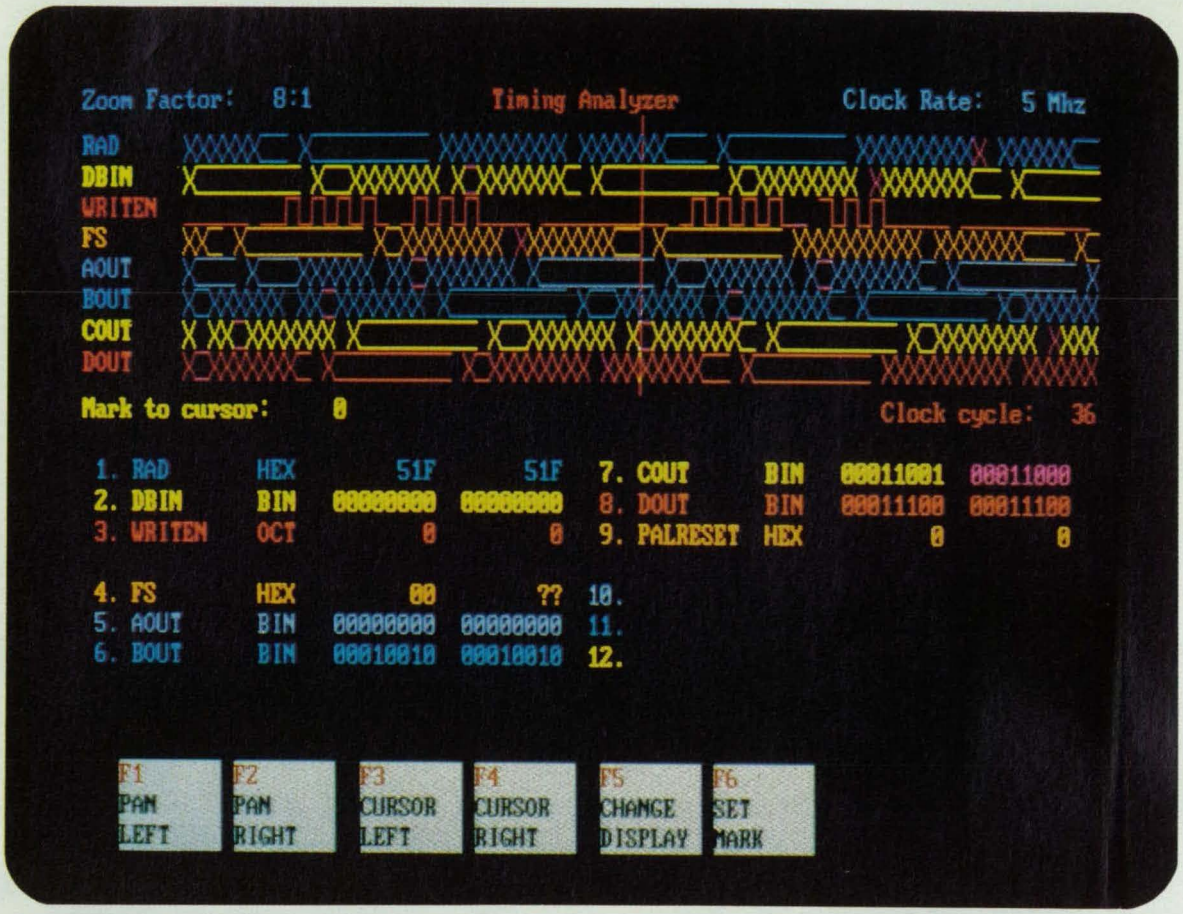

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NASA Tech Briefs
National Aeronautics and Space Administration

DECEMBER 1988
Volume 12 Number 11

SPECIAL FEATURES

TECHNICAL SECTION

ABP BPA

Slated for launch in October, 1989, the Galileo spacecraft will provide an in-depth study of Jupiter's gaseous atmosphere. See page 12. *(Artwork courtesy NASA)*

DEPARTMENTS

On The Cover: NASA's Hubble Space Telescope will enable scientists to gaze seven times farther into space than ever before, possibly to the edges of the visible universe. For more on this and other NASA projects planned for 1989, turn to page 12. *(Artwork courtesy NASA)*

Double Bonus

This month's technical section includes forecasts for 1989 and beyond by NASA experts in the following fields: Integrated Circuits (pg. 27); Communications (pg. 40); Computational Fluid Dynamics (pg. 53); Ceramics (pg. 60); Image Processing (pg. 64); Sensors (pg. 72); Dynamic Power (pg. 77); Superconductivity (pg. 85); Artificial Intelligence (pg. 90); and Flow Cytometry (pg. 93). The quotes provide a brief overview of emerging trends, and describe inventions and innovations being developed by NASA, other government agencies, and private industry that could make a significant impact in coming years.

A second bonus feature in this month's issue is the expanded subject index that begins on page 98. The index contains cross-referenced listings for all technical briefs appearing in NASA Tech Briefs during 1988.

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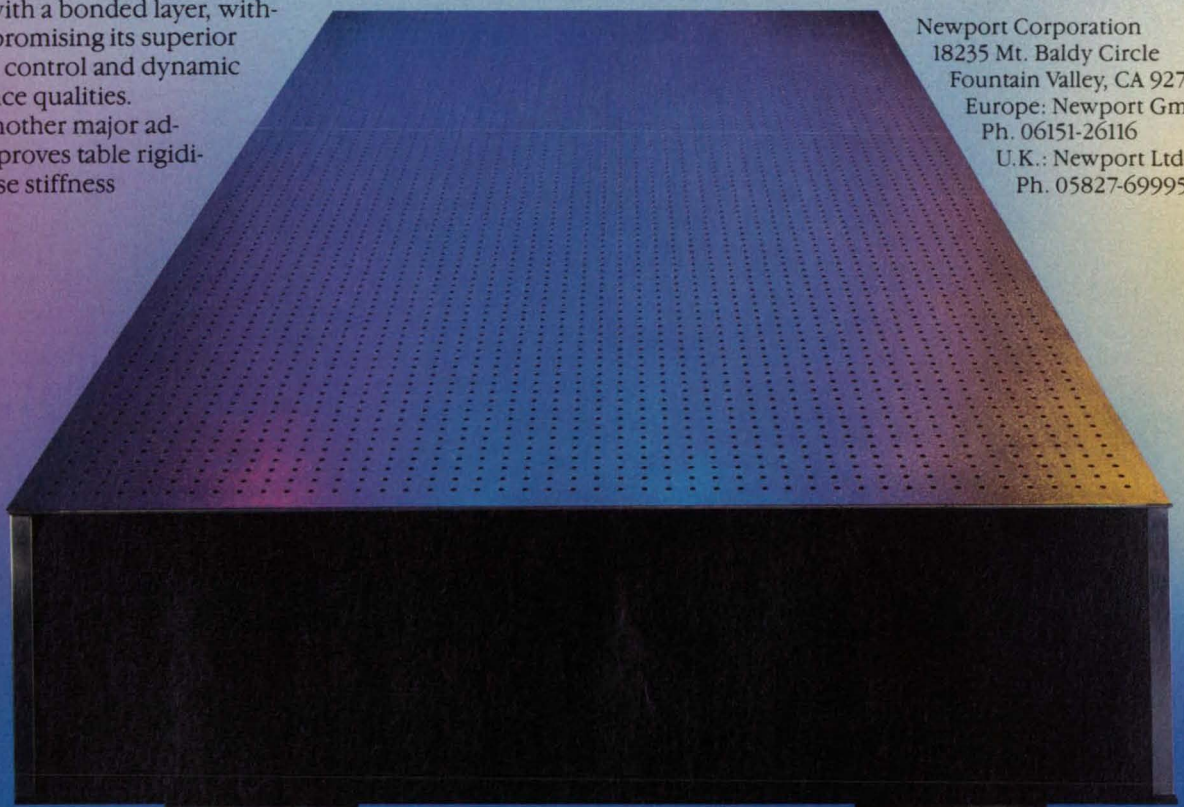

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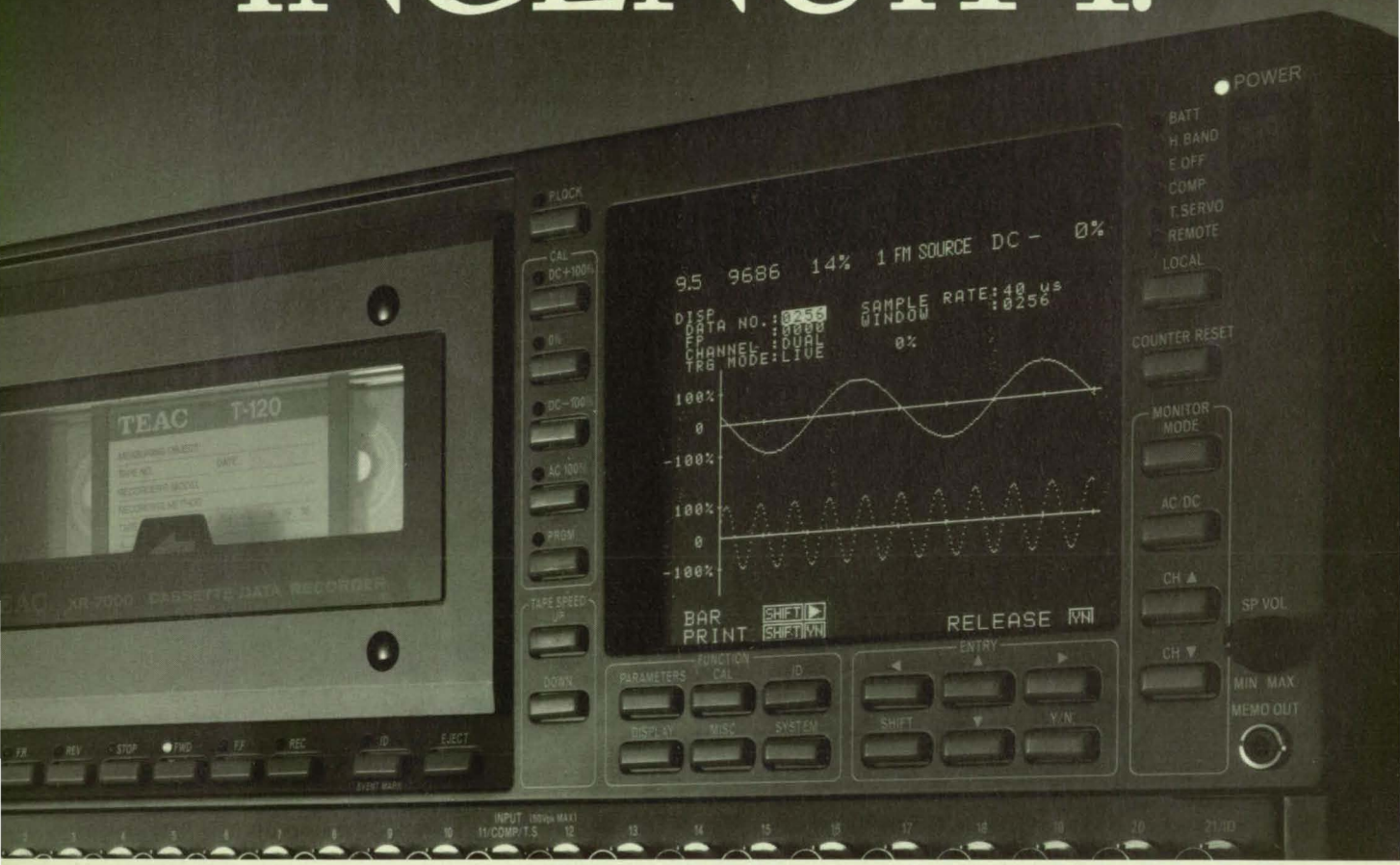

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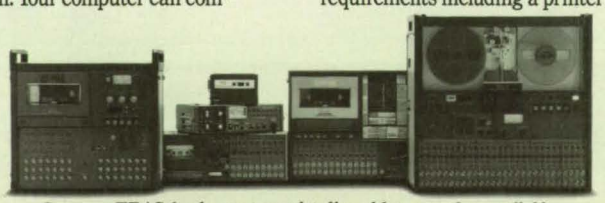

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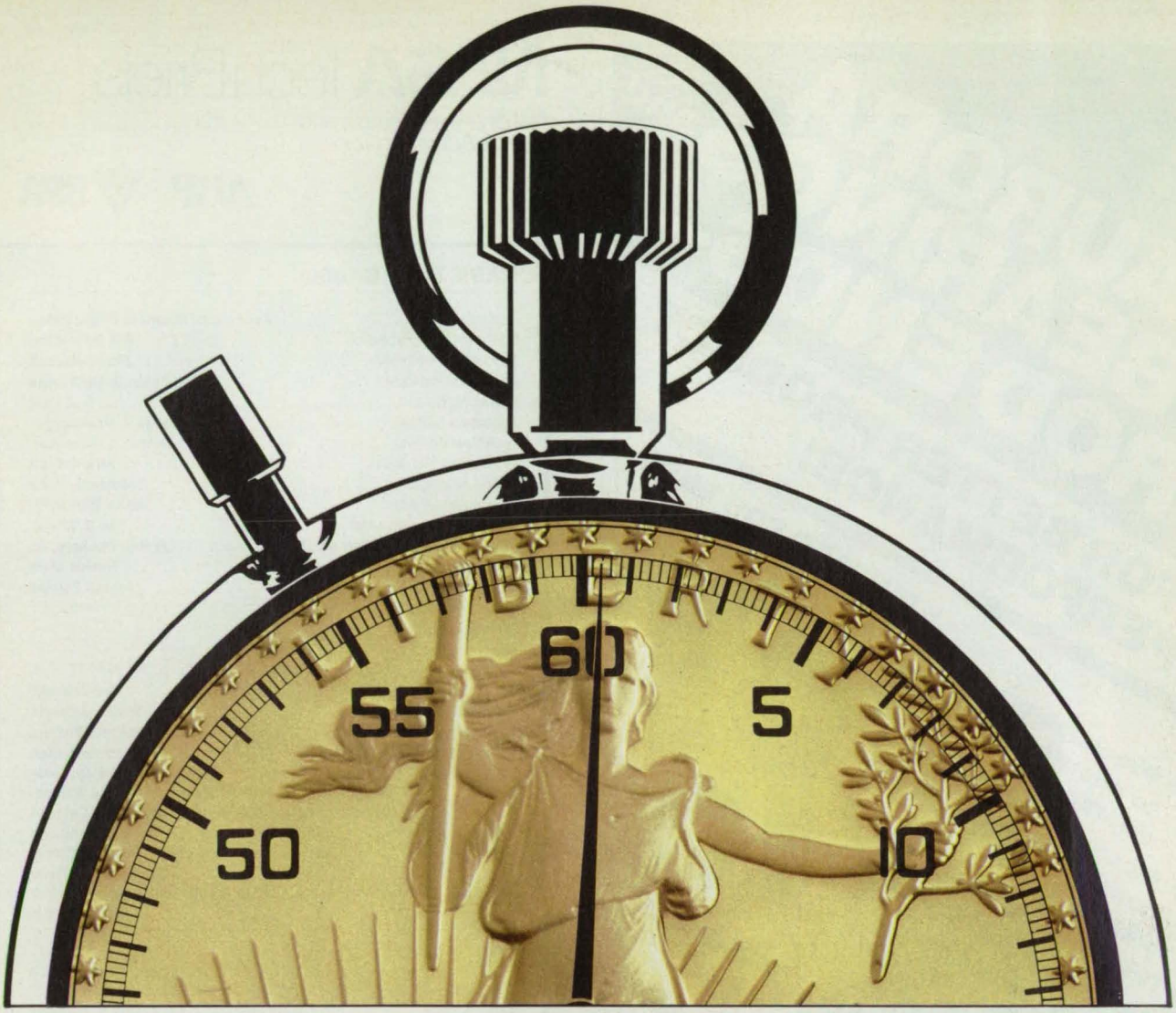

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NASA 1989: SPOTLIGHT ON SPACE SCIENCE

1989 promises to be a banner year for NASA's Space Science Program, with scheduled launches of two new planetary missions, the powerful Space Telescope, and an observatory specially designed to study the origin of the universe.

Right: ***An artist's concept of the Magellen spacecraft mapping Venus' surface.***
Far Right: ***A rendition of the Hubble Space Telescope.***

It has been called the greatest advance in astronomy since Galileo first pointed a telescope towards the heavens in 1609. NASA's Hubble Space Telescope, the largest scientific payload ever built for space, will extend Man's vision to the far reaches of the universe when it is placed in orbit by the Space Shuttle Discovery next December. Its highly sensitive components will enable astronomers to literally look back in time and observe the universe as it existed more than fourteen billion years ago, when galaxies were first being formed.

"The Hubble telescope could help us determine the ultimate fate of the universe," said Dr. Edward Weiler, Space Telescope Program Scientist for NASA's Office of Space Science and Applications. "By tracking the movements of galaxies over many light years, we may be able to find out whether the universe is an open or closed loop—whether it will continue to expand forever or eventually collapse on itself."

Managed by NASA's Marshall Space Flight Center, the 43-foot free-flying telescope will view in the visible and ultraviolet wavelengths. From a vantage point high above the Earth's murky atmophere, the Space Telescope will probe seven times deeper into space, detect objects 25 times fainter, and generate images of celestial bodies ten times clearer than possible with ground-based devices.

The orbit-serviceable observatory consists of a Systems Support Module, an Optical Telescope Assembly, and five science instruments. The Systems Support Module houses the optics and contains the electrical power supply, computers, and telemetry equipment. Digitized images and data will be transmitted from the telescope to NASA's Spaceflight Tracking and Data Network—which includes the Tracking and Data Relay Satellite System (TDRSS), the receiving station, and the NASA Communications Network—and then processed for use by scientists at the Space Telescope Science Institute in Baltimore, MD.

The Optical Telescope Assembly's key element is a 1826-pound primary mirror that comes within microinches of perfection. By comparison, if the Earth's surface could be polished as perfectly, the highest mountain would be only five inches tall. The assembly also features a system of fine guidance sensors that allows the telescope to precisely point to and lock on a target for long periods of time. "Its pointing stability is precise to within 0.007 seconds of arc," said Dr. Weiler. "That's the equivalent of hitting a dime with a laser beam from two hundred

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Today, almost all the latest aircraft have significant amounts of advanced composites. Much of the early proof of their performance came from a NASA-based program which documented real time experience with composites in both environmental specimens and actual aircraft components in service.

The results of NASA's program? More than 10 years of intelligence on how these new composites perform in continuous, everyday use. Recently, NASA released a detailed report reviewing their tests. It provides real proof of the acceptability of advanced composites. Here's a look at some of NASA's real world test results on parts reinforced with KEVLAR®

Lockheed L-1011 Fairings and Ailerons

In 1973, 18 KEVLAR*/epoxy fairings were installed on the L-1011's of three airlines. In continuous service now for over 14 years, these KEVLAR fairings have proved to be as trouble free as their fiberglass counterparts. This fact has been confirmed by 14 annual inspections. In all likelihood, these fairings will remain in service until the airplane itself is retired.

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Bell 206L Doors and Fairing

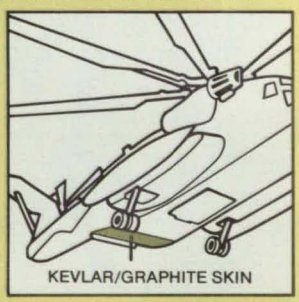
In 1981, 40 shipsets of KEVLAR/epoxy litter and baggage doors and forward fairing were installed on Bell 206L helicopters. The service experience with the KEVLAR forward fairing has been excellent. On the KEVLAR litter door there were some early service problems with the metal hinges and plexiglass windows, but these have been corrected and the door is now performing without problems.

There have been some disbond problems with the KEVLAR baggage door caused by inadequate resin filleting between the skin and core. However, this problem can be easily fixed by adding a film adhesive between the skin and core during layup or by selecting a different resin or resin content for the skin prepreg material. With the exception of the baggage door disbonding, all of these components are performing better than their metal production counterparts.

KEVLAR/EPOXY DOORS AND FAIRING

Sikorsky CH-53D Cargo Ramp

A KEVLAR/graphite skin was installed on the aft end of a USMC CH-53D cargo ramp for service evaluation in 1981. The objective of this evaluation was to assess the durability of the KEVLAR skin in a severe ground-handling environment. Annual inspections have revealed no damage, and no other service problems have been reported.



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NASA Summary

Perhaps the last paragraph of the NASA report best summarizes this highly successful and productive program: "In general, the composite components have performed excellently during the 13-year flight service evaluation. The moisture absorption for the flight components is lower than the moisture absorbed for unpainted ground-based exposure specimens. Strength retention for the composite components is as good or better than strength retention for ground-based exposure specimens with comparable exposure periods. The success of these components has led transport and helicopter manufacturers to make production commitments to selected composite components."

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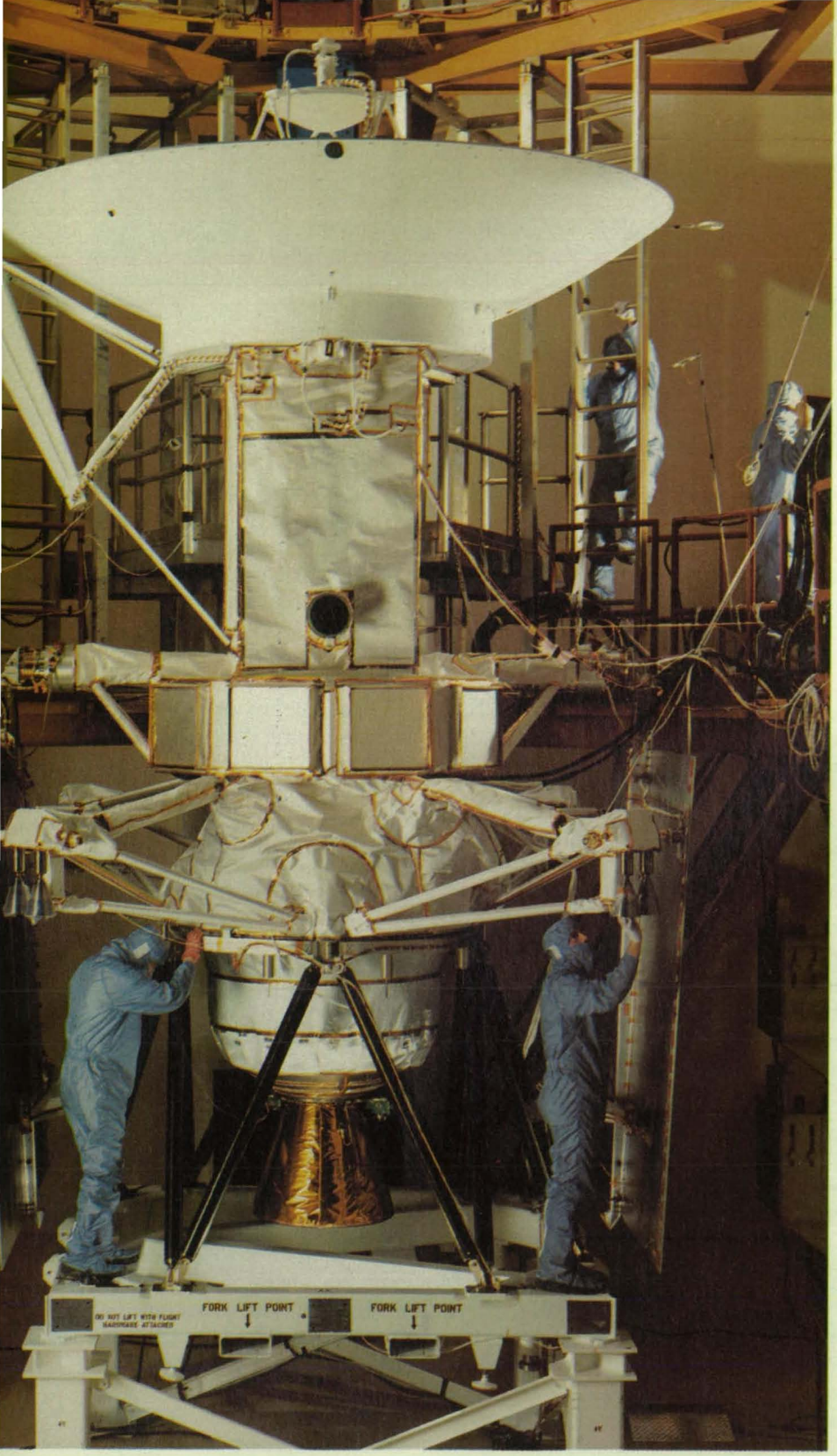

Magellen, shown here after successfully completing a series of noise and vibration tests, will map the surface of Venus using an advanced radar that can penetrate the planet's thick, poisonous clouds. *(Photo courtesy Martin Marietta Corp.)*

miles away."

Among the craft's instruments is a wide field camera that gathers 30 million bits of information per picture, which astronomers will use to measure the positions of bright stars. "If a star's motion is erratic—if it wobbles—then we know something is pulling on it, perhaps a large planet that we've yet to discover," explained Weiler.

A second camera, provided by the European Space Agency, will photograph celestial objects so faint that cumulative exposures over many orbits will be needed to produce a clear image. This instrument may help determine the distance to the Magellanic Clouds, which in turn will permit calibration of other celestial gauges such as the Cepheid variables.

One of Hubble's dual spectrographs will be used in the ultraviolet spectral regions to investigate the composition of the interstellar medium, which plays a fundamental role in the evolution of stars. New stars are formed from dense clouds of interstellar gas and dust, while old stars return their material to the interstellar medium.

The other spectrograph will help determine the constitution and dynamics of faint objects such as quasars, some more than fourteen billion light years away. The most powerful energy sources in the universe, quasars emit the radiation of a hundred galaxies combined. Scientists are eager to learn how quasars gained their strength and what part they played in the early development of the universe.

Another potent light source—the pulsar—will be tracked by the telescope's high-speed photometer. Formed from the collapsed remnants of supernovae explosions, pulsars generate beams of directional radiation that sweep across space like lighthouse beacons.

"During its 15-year lifetime, the Space Telescope may see features of the universe which at present can't even be guessed," said Jean Olivier, Deputy Project Manager of the Hubble Space Telescope Office at Marshall. "It's probably this aspect of the project, the unknown, that most excites astronomers."

Venus Mapper

The Hubble mission will cap a year of unprecedented space science activity, with the planned launches of three other major projects and the start of work on a fourth.

In April, NASA will launch its first planetary mission since Voyagers 1 and 2 left Earth in 1977. Called Magellen, the Martin Marietta-built spacecraft will embark on a 16-month journey to Venus. Once in Venetian orbit, Magellen will deploy a synthetic aperture radar to pierce the planet's thick sulfuric acid and carbon dioxide cloud cover and capture pictures of its shrouded surface. The craft will map nearly the entire surface over a three year period, with resolutions ten times better than obtained by recent Soviet missions. The sharper images should reveal small-scale features such as volcanoes, craters, faults, lava flows, erosion channels, and possibly ancient ocean basins.

"There are striking similarities in size, density, and composition between Venus and Earth, yet the two planets have evolved in dramatically different fashions," said John Gerpheide, Magellen Project Manager for NASA's Jet Propulsion Laboratory (JPL). "By better understanding this neighbor planet's development, we may gain some insight into the precariousness of our own environment, and how vital it is that we take steps to protect it."

Big Bang Theory

Next up will be the Cosmic Background Explorer (COBE), a Goddard-

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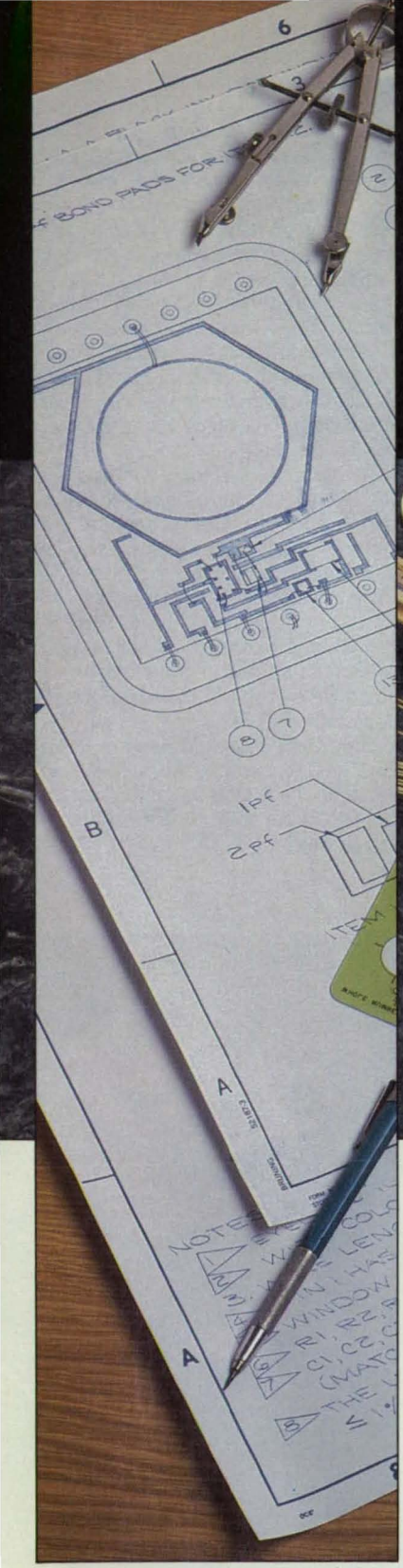

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developed observatory slated for lift-off in June aboard a Delta expendable launch vehicle. During its year-long mission, COBE will measure and map the infrared and microwave background radiation believed to be leftover from the primevel explosion called the Big Bang. According to this theory of the universe's origin, a cataclysmic explosion occured 15 billion years ago and triggered an expansion of the cosmos that has continued ever since. Scientists hope to support the theory through evidence gathered by COBE.

COBE's three instruments—the Differential Microwave Radiometer, the Far Infrared Absolute Spectrophotometer, and the Diffuse Infrared Background Experiment—will also determine the radiation spectrum and the variances between different points in the sky with a new degree of sensitivity. The latter instrument will search for light from the first stars and galaxies, never before possible because Earth's atmosphere distorts measurements and dust in the Milky Way Galaxy confuses analysis.

TDRSS will provide telemetry and command for the orbiting observatory. Data relayed to Goddard via the satellite system will be processed and then stored at the National Space Science Data Center in Greenbelt, MD, where it will be available to cosmotologists and the public as both printouts and maps.

Into The Fire

Scheduled for October is the long-awaited Galileo mission to Jupiter, a cooperative effort with the Federal Republic of Germany that will provide the most comprehensive investigation yet conducted of a planet other than Earth.

"Jupiter is viewed as a star that never quite made it," said Richard Spehalski, Galileo Project Manager for JPL. "It never collected enough mass to sustain the temperatures needed for a fusion reaction. Even after billions of years, however, Jupiter still radiates about twice as much energy as it receives from the Sun, and could hold some crutial clues as to how our solar system was formed."

The Shuttle Atlantis will place Galileo in low Earth orbit. A rocket will then boost the craft towards Venus, whose gravity will be used as a "slingshot" to accelerate Galileo on a path to Jupiter.

As it nears the giant planet in mid-1995, Galileo will release a probe that will descend by parachute into the Jovian atmosphere. Protected by a heat shield from temperatures expected to reach 14,000 degrees Fahrenheit, the probe will survive for about one hour before being crushed under the tremendous pressure and then vaporized by the heat. In that short span, however, the probe will relay substantial information about Jupiter's composition and mass to the orbiter flying overhead. Galileo, meanwhile, will swing into orbit around the planet and transmit back to Earth—for at least two years— instrument data and high-resolution photographs of Jupiter and its four inner moons.

Mysterious Matter

During the coming year, development will continue on a number of missions planned for launch through 1993. These include the Gamma Ray Observatory, designed to study gamma ray energies up to 30 billion electron volts; the Wind, Polar, and Geotail satellites of the Global Geoscience Program; the Ulysses mission to the Sun's polar region; and the Mars Observer, which will conduct an extensive investigation of the Martian climate and soil.

NASA also will begin work in 1989 on the Advanced X-ray Astrophysics Facility, a ten-ton telescope that will explore the cosmos in the x-ray region of the electromagnetic spectrum. The observatory, to be built by TRW, Inc. under the Marshall Center's supervision, will be serviced in orbit by crews of either the Shuttle or Space Station during its 15-year operation period.

Scientists anticipate using the x-ray telescope to investigate the mystery of the "missing mass." About 90 percent of the matter in the universe is invisible; its existence is known only through the gravitational force it exerts on visible celestial bodies. AXAF could locate and weigh this "dark" matter in galactic clusters, perhaps identifying differences among the clusters that would shed light on its identity.

AXAF will focus on spinning neutron stars, composed of matter so dense that a single teaspoon full would exceed the combined weight of every person on Earth, and black holes, vast gravity pits from which even light cannot escape. Matter falling into these pits would release x-ray emissions. By imaging the emissions with AXAF, astronomers hope to pinpoint the location of black holes.

The x-ray observatory also will be an important new tool for research in plasma physics, the fundamental properties of matter, and the laws of physics. It may even provide information from which astonomers can deduce the exact age of the universe.

AXAF will be the third member in NASA's family of "Great Observatories," following the Space Telescope and the Gamma Ray Observatory into orbit in 1996. The fourth and final member will be the Space Infrared Telescope Facility, which has not yet been funded. Together, the Great Observatories will enable simultaneous studies of cosmic sources across a wide range of the electromagnetic spectrum.

"Once these observatories are up in space," said Robert Lessels, a Marshall spokesman, "the United States will be the world's focal point for astronomical investigation." □

With a geometric collecting area of 1,700 square cm and an 0.5-arcsecond angular resolution, the Advanced X-ray Astrophysics Facility (AXAF) will provide a hundred-fold increase in sensitivity over its predecessor, the High Energy Astronomical Observatory-2.

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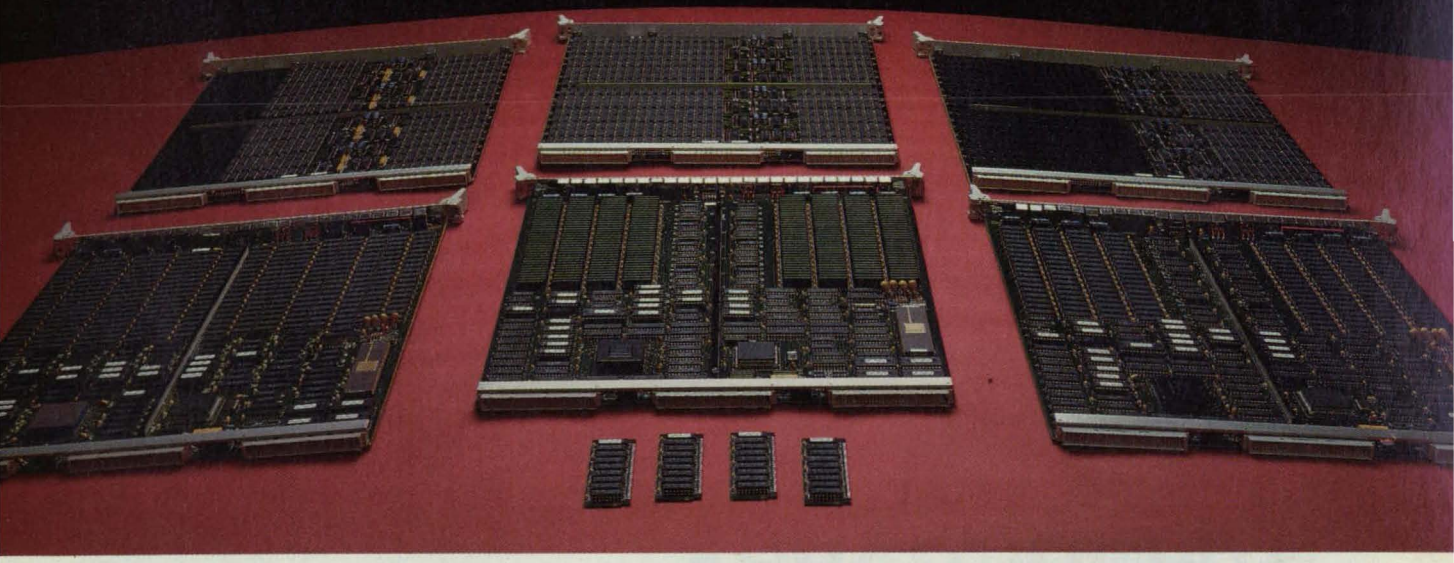

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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 20). NASA's patent-licensing program to encourage commercial development is described on page 20.

Quick-Disconnect Valves for Modular Fluid Systems

Quick-disconnect valves are being developed for modular fluid systems. The valves can be used with or without modifications in a variety of liquid and low-pressure-gas systems. The design minimizes the loss of liquid and the ingestion of gas or other contaminants during connection and disconnection. (See page 69).

High-Capacity Aeronautical Satellite Communication System

A high-capacity satellite communication system provides safety-related communications to growing air traffic. The system — primarily designed to serve aircraft en route — provides 5,093 forward communication channels and 7,093 reverse channels. (See page 30).

Experimenting With Baroreceptor Reflexes

A chamber, called a Baro-Cuff, was developed to study the blood-pressure-reflex responses of astronauts in outer space. Strapped to the neck of a human subject, the chamber applies pressure or suction of controlled magnitude and duration to the carotid arteries. It may also be useful for studies of patients with congestive heart failure, chronic diabetes mellitus, and other conditions. (See page 92).

Measuring Time-Averaged Blood Pressure

A device measures the time-averaged (static) component of absolute blood pressure in an artery instead of the usual diastolic and systolic extremes of pressure created by the heart's pumping action. The device includes a compliant cuff around the artery and an external monitoring unit. (See page 93).

This symbol appears next to technical briefs which describe inventions having potential commercial applications as new products. The process for developing a product from a NASA invention is described at the top of this page.

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If you need further information about new technologies presented in *NASA Tech Briefs,* request the Technical Support Package (TSP). If a TSP is not available, you can contact the Technology Utilization Officer at the NASA Field Center that sponsored the research. He can arrange for assistance in applying the technology by putting you in touch with the people who developed it. If you want information about the patent status of a technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Refer to the NASA reference number at the end of the Tech Brief.

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Electronic Components and Circuits

Stacked Metal Silicide/Silicon Far-Infrared Detectors

The long-wavelength limit would be extended.

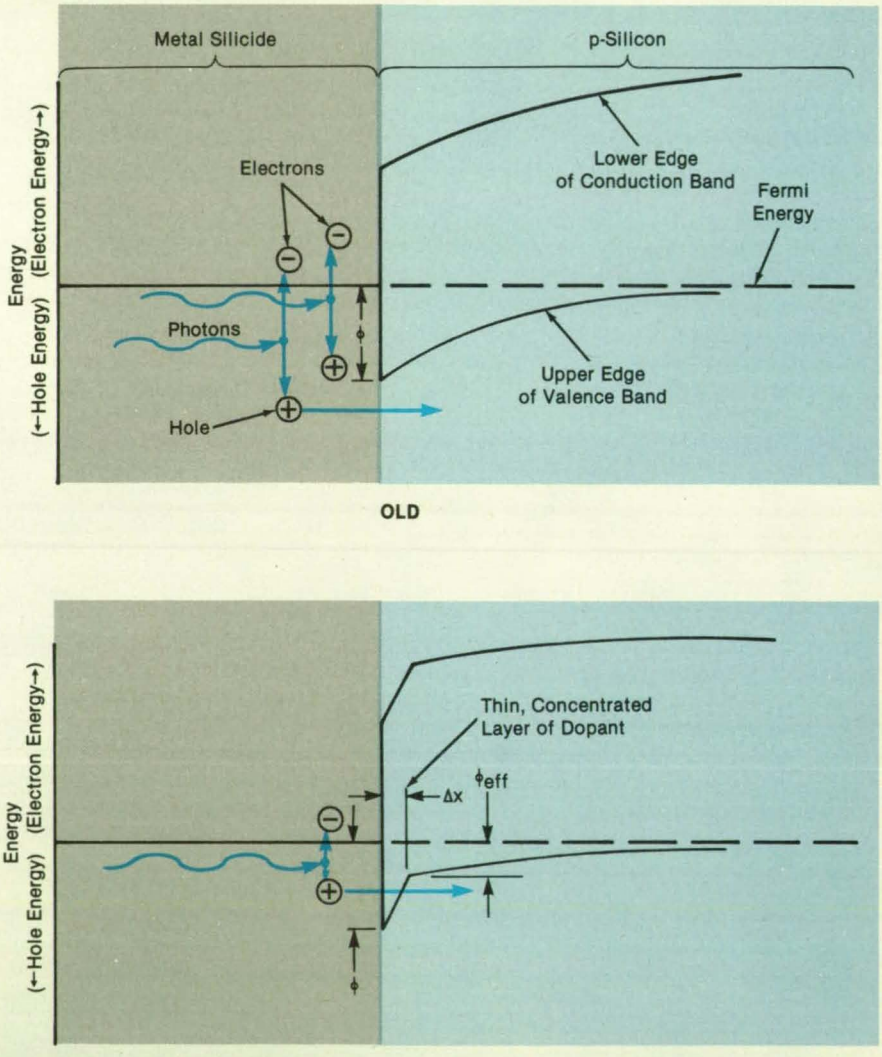
NASA's Jet Propulsion Laboratory, Pasadena, California

Selective doping of the silicon in a proposed metal silicide/silicon Schottky-barrier infrared photodetector would increase the maximum detectable wavelength. Stacking the layers to form multiple Schottky barriers would increase the quantum efficiency of the detector. Detectors of the new type would enhance the capabilities of far-infrared imaging arrays.

In a conventional detector of this type, a Schottky barrier is formed at the interface between a PtSi or Pd_2Si contact and positively doped silicon, as shown at the top of the figure. Photons absorbed in the silicide near the interface produce holes, the maximum energies of which equal the photon energy. Holes of energy greater than the barrier height, ϕ, pass by the barrier and are collected in the silicon as photocurrent. The maximum detectable wavelength is the wavelength of photons of the minimum detectable energy ϕ.

In the proposed detector a thin layer of very high positive dopant concentration would be placed in the silicon at a small distance Δx from the interface. This layer would reduce the width of the peak in the Schottky barrier as shown at the bottom of the figure, permitting significant numbers of holes to tunnel quantum mechanically through the barrier. The tunneling would reduce the effective height of the barrier to a lower value, ϕ_{eff}. Thus, the maximum detectable wavelength would be increased to that of photons of energy ϕ_{eff}.

The quantum efficiency of a typical Schottky-barrier detector is only about 1 percent. If the device is made with multiple Schottky barriers, the quantum efficiency should be increased because each photon would then have multiple opportunities to photoexcite holes in the thin metal silicide layers. To realize an overall quantum efficiency of about 10 percent or better in a multiple-layer device, the metal silicide layers be thinner than about 10 nm; that is, substantially less than a mean-free-path length for the photoexcited holes. This assures that the holes have repeated opportunities of being collected at one of the interfaces before losing their energy by inelastic collisions.

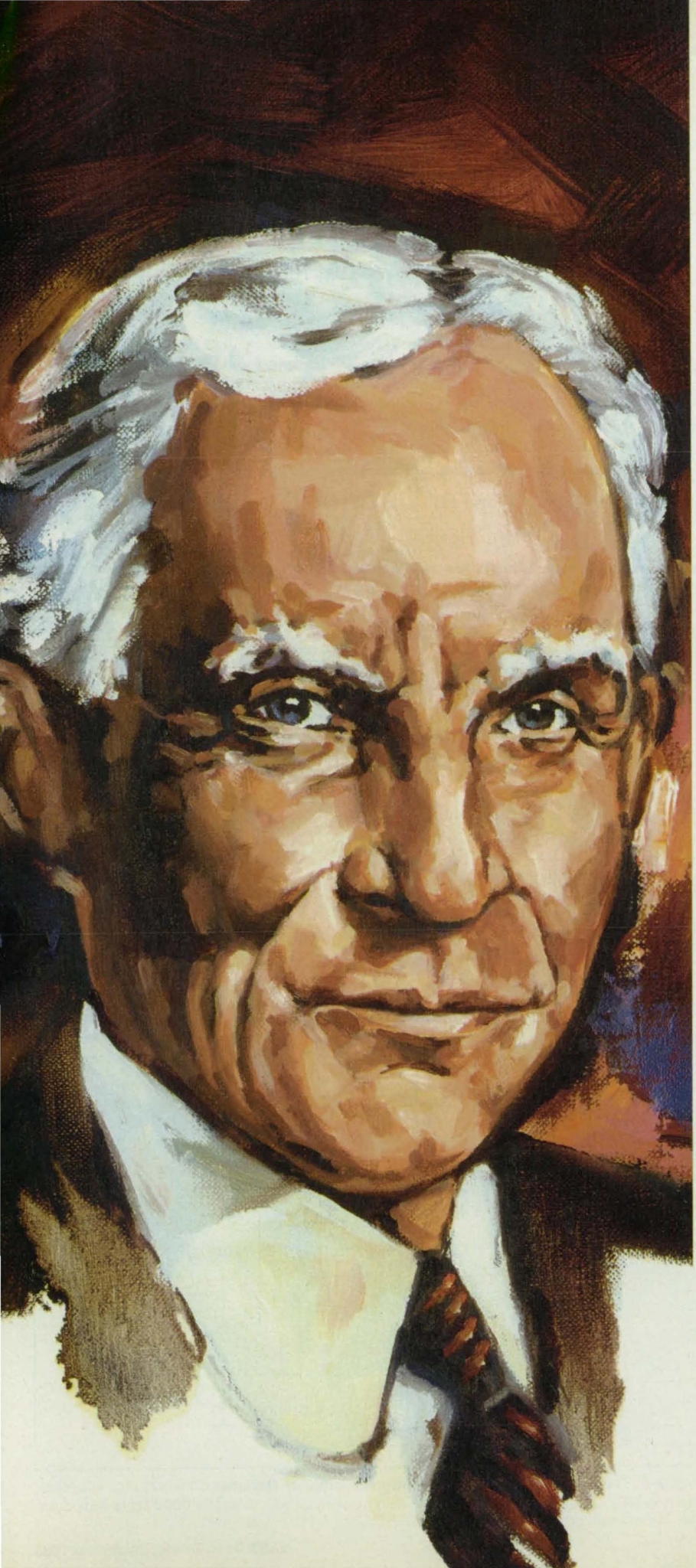


A Thin, Concentrated Layer of Dopant would narrow the Schottky barrier, reducing its effective height from ϕ to ϕ_{eff}.

Detectors of the new type could be grown by molecular-beam epitaxy on silicon wafers that also contain very-large-scale integrated circuits. Thus, imaging arrays of detectors could be made in monolithic units with image-preprocessing circuitry.

This work was done by Joseph Maserjian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 154 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-17194.



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Henry Ford
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Selecting Wire Sizes for Switching Power Supplies

A computer program eliminates trial and error.

NASA's Jet Propulsion Laboratory, Pasadena, California

A computer program determines the size and number of strands of wire for low resistance at high frequency in switching power supplies. Engineers are designing such power supplies to switch at ever-higher frequencies to reduce the sizes and weights of transformers and other inductors. Switching frequencies of 200 kHz are not unusual, and some supplies switch as fast as 1 MHz. At these high frequencies, currents become concentrated at the surfaces of conductors (the skin effect), increasing the effective resistances and wasting energy. The waste can be reduced by using stranded wire instead of solid wire, but until now the diameter of the wire and the appropriate number of strands had to be selected by trial and error.

The only inputs required by the program are the switching frequency, the specified current, and the specified current density. First, the program calculates the skin depth as a function of frequency. It chooses a strand of standard-gauge wire, the radius of which closely approximates the skin depth. It calculates the total required cross-sectional area of bare wire from the ratio of the current to the current density. The number of strands is then calculated as that which has a total cross-sectional area close to the required area.

This work was done by Colonel W. T. McLyman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 88 on the TSP Request Card.*
NPO-17279

Frequency-Accommodating Manchester Decoder

No adjustment is necessary to cover a 10:1 frequency range.

Lyndon B. Johnson Space Center, Houston, Texas

A decoding circuit converts biphase-level pulse-code modulation to nonreturn-to-zero (NRZ)-level pulse-code modulation plus a clock signal. The circuit accommodates an input data rate of 50 to 500 kb/s. It tracks gradual changes in the rate automatically, eliminating the need for extra circuits and manual switching to adjust to different rates.

The circuit (see Figure 1) is based on the 3/4-data-cell one-shot decoder, which synchronizes itself to biphase data and yields NRZ data and a 75-percent-duty-cycle clock. It may initially synchronize with phase-change transitions and produce incorrect output, but resynchronizes itself to clock transitions at the first 0-to-1 or 1-to-0 data pattern, thereafter giving a correct output. The new decoder is a 3/4-cell one-shot that continuously adjusts its period to remain at 75 percent of the input data-cell period over a range of input rates.

The input signal triggers Z_1, a bidirectional one-shot. The Z_1 timing components are selected to produce a timing period longer than the longest data cell (from the lowest frequency) to be decoded. The Q output of Z_1 goes high, starting a ramp generator consisting of Z_2, Q_1, R_2, and C_2. As time passes, the output of the ramp generator rises and is monitored by the positive input of comparator Z_3. When the ramp reaches reference voltage V_{ref} at the negative input of Z_3, the output of Z_3 goes high, clearing and prematurely terminating the output pulse of Z_1. This, in turn, resets the ramp generator to 0 V. Z_1 then remains idle until the next input data transition (Figure 2).

Voltage V_{ref} is generated as follows: Z_4 is connected in feedback to toggle with each output pulse of Z_1. The output of Z_4 oper-

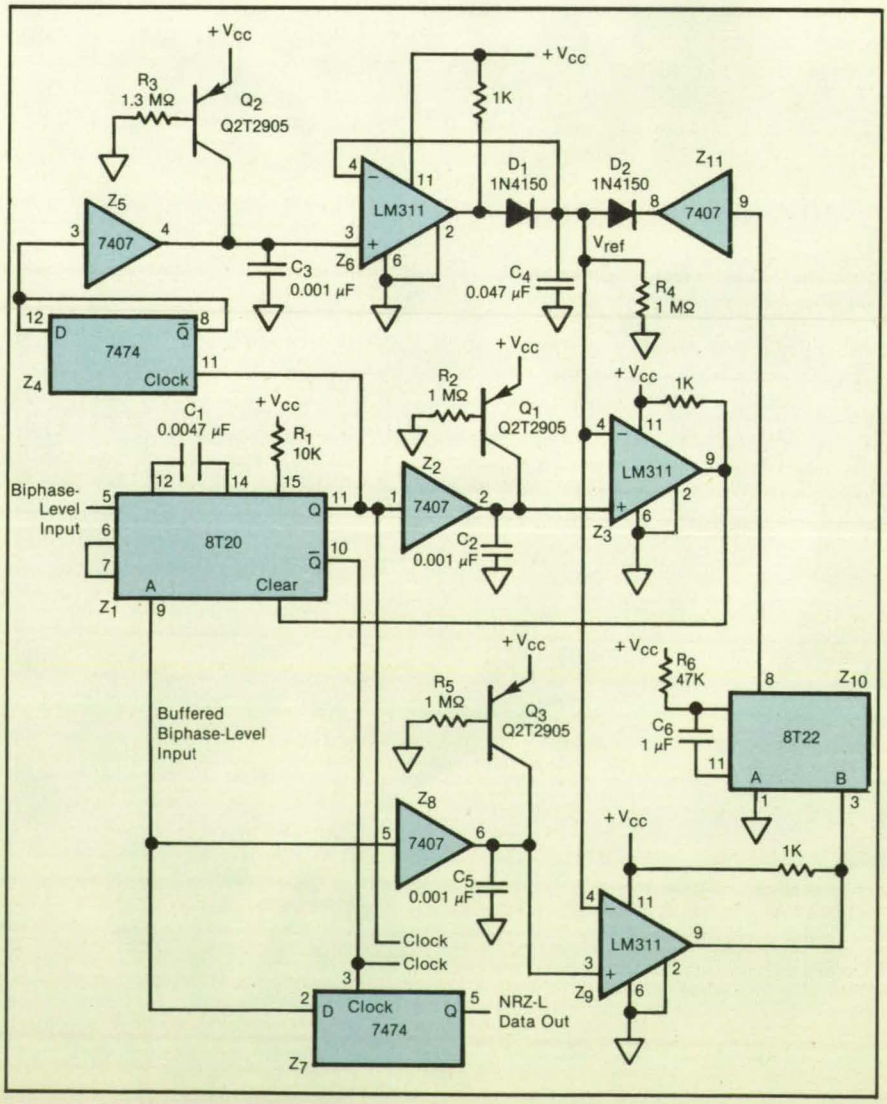


Figure 1. The **Frequency-Accommodating Manchester Decoder** converts biphase-level input to NDZ-L output at any input data rate from 50 to 500 kb/s. The decoder is based on the ¾-data-cell one-shot circuit.

ates a second ramp generator (Z_5, Q_2, R_3, and C_3). This produces a waveform with a peak amplitude directly proportional to the period of the data cell. This waveform is peak-detected by Z_6, D_1, C_4, and R_4, producing V_{ref}, a dc level representing the period of the data cell.

The data-cell ramp (at C_3) is designed to give a peak near V_{cc} for the longest data cell to be handled. The ¾-cell ramp generator (at C_2) is designed with a time constant of three-quarters that of the data-cell ramp generator. Therefore Z_1 is cleared at 75 percent of the data-cell period.

Once synchronized with the input, V_{ref} is generated to represent the incoming data rate. V_{ref} and the ¾-cell ramp produce a ¾-cell one-shot function of Z_1. The biphase input is connected to the D input of Z_7 through the A output of Z_1. Z_7 is clocked with the inverted output of Z_1 to yield the NRZ-L data. The output of Z_1 may be used as a clock for the NRZ-L data.

This work was done by Mario J. Vasquez of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 13 on the TSP Request Card.*
MSC-21312

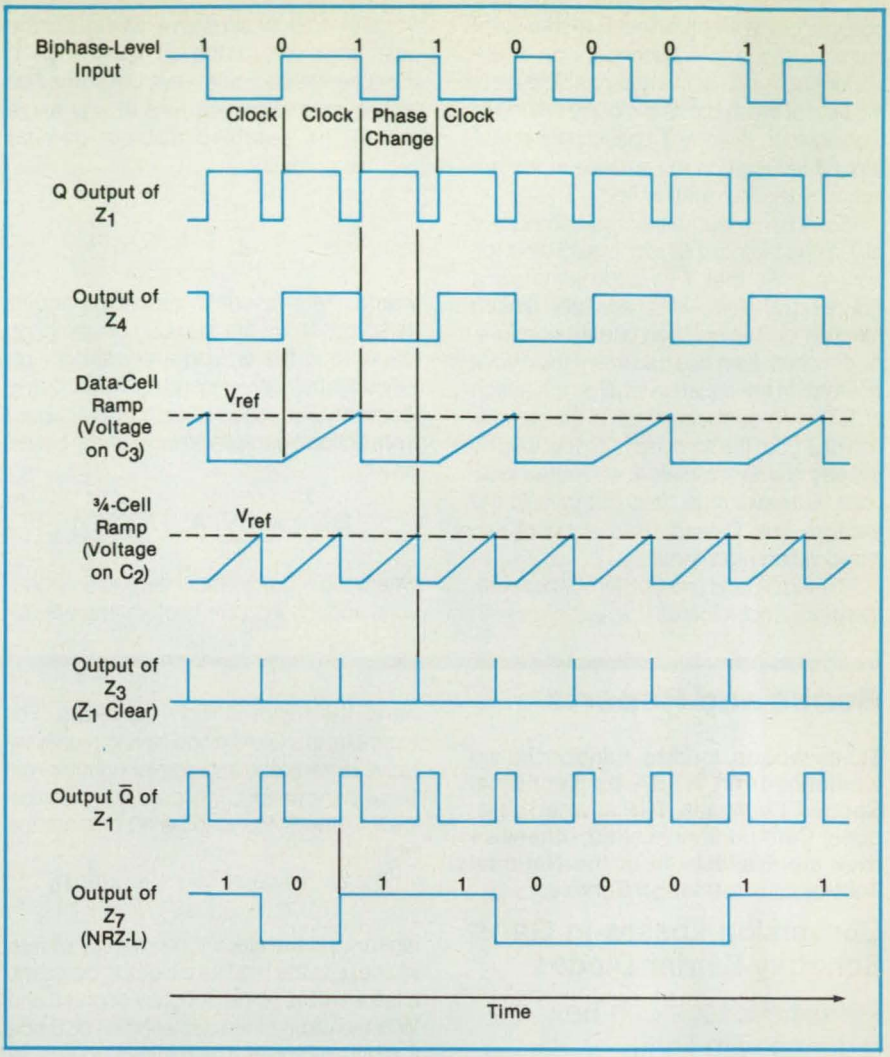


Figure 2. These **Waveforms Are Produced by the Decoder** when it is operating in synchronism with the biphase-level input signal.

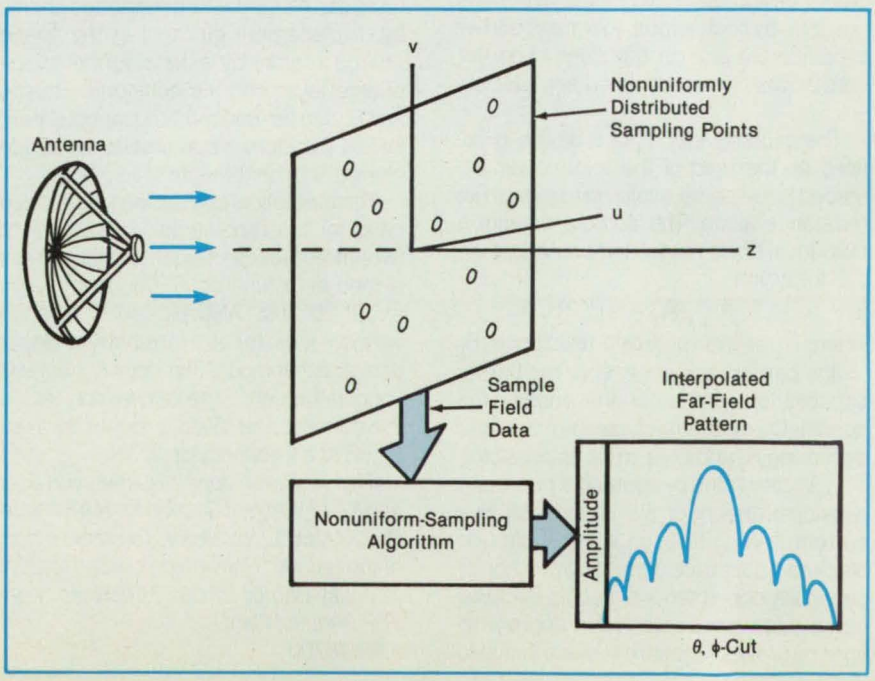
Nonuniform Sampling of Radiation From Antennas

Far-field patterns can be reconstructed.

NASA's Jet Propulsion Laboratory, Pasadena, California

A mathematical technique constructs the far electromagnetic field of a paraboloidal or other antenna at desired angular intervals by interpolation from measurements of the far fields (amplitude and phase) at sparsely and unevenly distributed locations (see figure). This is a two-dimensional sampling technique, the form of which depends only on the measurement locations and not on the measured field values. Nonuniform sampling could be particularly useful where the movements of the measured or measuring antenna cannot be controlled precisely. One recent example is the proposed measurement concept of large antennas aboard the Space Shuttle.

The technique is applicable to any com-



The **Nonuniform-Sampling Technique** uses an interpolation algorithm to obtain the far-field radiation pattern of an antenna at any point *u*, v based on measurements at a few sampling points.

ponents of the electric field **E** at measurement locations in a spherical coordinate system centered at the antenna. The electric field at these points is closely related to the radiation integral **T** based on the currents **J** induced on the surface of the antenna by the illuminating field.

If one can assume that the component of **T** along the polar (*z*) axis is negligible (or, equivalently, that **T** is approximately a Fourier transform of a spatially limited function or that one can use an aperture-field model), then one can invert the matrix operator in the equation for **E** as a function of **T**. This amounts, in effect, to the calculation of **J** from the samples of **E**, followed by the use of **J** to calculate **E** at desired locations. However, one does not calculate **J** explicitly but, instead, uses either of two interpolation algorithms.

The algorithms use Cartesian measurement-point coordinates u, v, using $u = \sin\theta\cos\phi$ and $v = \sin\theta\sin\phi$, where θ is the polar angle and ϕ is the azimuthal angle in the spherical coordinate system. In the first algorithm, the electric field at any angle within the sampled domain can be reconstructed by

$$\mathbf{E}(u,v) = \sum_{i=1}^{N} \mathbf{E}(u_i, v_i)\,\psi_i(u,v)$$

where the subscripts denote particular samples, N = the number of sampling points, and the $\psi_i(u,v)$ are interpolation functions that only depend on the sampling locations. The second algorithm is adapted from uniform-sampling theory and is based on

$$\mathbf{E}(u,v) = \sum_{n,m} \mathbf{A}_{nm}\,F_{nm}(u,v)$$

where the F_{nm} are other interpolation functions and the $\mathbf{A}_{nm}$ are vectors that are obtained by matrix inversion and depend on both the field values and the sampling locations.

The sampling window can be shifted from the main beam to the side-lobe region. Numerical simulations show that the sampling technique can recover the side lobes at relatively wide observation angles, even without any knowledge of the main lobe. Moreover, one can reconstruct the far-field pattern over a wide angular range by combining the far fields obtained by sampling over narrower adjacent or overlapping ranges. Many measurements have been performed to demonstrate the accuracy of the technique.

This work was done by Y. Rahmat-Samii and R. L. Cheung of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 67 on the TSP Request Card.*
NPO-16961

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Conversion Losses in GaAs Schottky-Barrier Diodes

Parasitic losses can be reduced with lightly doped epitaxial layers of proper thickness.

A report presents calculations of conversion losses in Schottky-barrier diodes. This theoretical work is directed toward the reduction of parasitic losses through the proper design of space-charge layers: it is possible, by such efforts, to reduce barrier capacitances and contributions to barrier resistances from undepleted epitaxial layers.

The parasitic loss, L, of a device is defined as the ratio of the total power absorbed to the power available to the barrier resistance alone. The authors present a cylindrical diode model and equivalent circuit for which

$$L = 1 + R_s/R_b + \omega^2 C^2 R_s R_b$$

where R_s = the spreading resistance, R_b = the barrier resistance, C = the barrier capacitance, and ω = the angular frequency. Consequently, L can be minimized by making R_s and C as small as possible.

R_s is calculated by applying a previously developed theory of the impedance to a current flowing through a small circular disk into a substrate consisting of a homogeneously doped semiconductor. Because terms that were neglected in approximations by previous researchers are included here, the result is more accurate. For example, in a GaAs diode having representative dimensions and semiconductor-material parameters, the previous approximate value is found to be 30 percent too high.

The barrier capacitance is given by

$$C = \varepsilon_0\varepsilon_r\pi a^2/W$$

where ε_0 is the electric permittivity of free space, ε_r is the relative dielectric constant, a is the radius of the Schottky contact, and W is the width of the depletion layer. Since C must be kept small to minimize losses, W must be made large. This can be done by decreasing the dopant concentration, but then the contribution of the undepleted epitaxial layer to R_s increases because the light doping reduces the conductivity.

However, the epitaxial-layer ac resistance can be avoided if the alternating currents can be made to be supported entirely by displacement currents in the space-charge region, by extending the space-charge layer into the substrate. Thus, C and R_s can be reduced simultaneously and losses therefore made smaller by space-charge "punch-through."

The theoretical conversion loss is calculated for the representative GaAs diode (which achieves "punch-through") and plotted as a function of frequency, up to about 10 THz. Also plotted is the conversion loss for a more-heavily-doped conventional model that does not achieve "punch-through." The conversion loss of the conventional diode is higher by about 22 dB at a frequency of 10 THz.

This work was done by Oldwig von Roos and Ke-Li Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Conversion Losses in GaAs Schottky-Barrier Diodes," Circle 44 on the TSP Request Card.*
NPO-16700

Response of a MOSFET to a Cosmic Ray

Susceptibility to single-event upset is analyzed.

A theoretical paper discusses the response of an enhancement-mode metal oxide/semiconductor field-effect transistor (MOSFET) to a cosmic-ray ion that passes perpendicularly through its gate-oxide layer. Even if the ion causes no permanent damage, the temporary increase of electrical conductivity along the track of the ion can be large enough and last long enough to cause a change in the logic state (a single-event upset) in a logic circuit that contains the MOSFET.

The gate of the MOSFET is modeled as a simple structure resembling a multilayer parallel-plate capacitor of capacitance C_{ox} with the aluminum gate as the positive electrode, the oxide layer as the insulator, and the n-channel and depletion layer as parts of a structured negative electrode. The effects of the external circuitry are summarized by a gate/source bias voltage V_{GS} applied through a Thévenin equivalent resistance R_T. The effect of the ion on the circuit is represented by a resistor R_C across the capacitor.

The increase in conductivity along the ion track is attributed to the creation of electron/hole pairs, the density of which is computed from a simple model involving the stopping power of the oxide with respect to ions of a given energy. The hole current and the diffusion currents of electrons and holes are assumed to be negligible: One of the consequences is that the duration of the ion track is governed by the recombination of holes and electrons. A typical recombination time is about 1 μs.

The analysis shows that R_C is inversely proportional to the stopping power and independent of the cross-sectional area of the ion track. Assuming values of R_C and C_{ox} typical of those in real devices, the ion track discharges the gate capacitor from the bias voltage V_{GS} to a lower voltage $[R_C/(R_C+R_T)]V_{GS}$ within about 1 ns or less time. If this lower gate voltage is less than the threshold V_T, then the MOSFET turns off and remains off for the duration of the ion track.

If the affected MOSFET is one of a pair that forms a bistable circuit, then the other MOSFET (with a typical turn-on time of a few nanoseconds) turns on, thus completing the single-event upset. The vulnerability to single-event upset can be reduced by designing the circuit to prevent the gate voltage from going below V_T. One way is to increase V_{GS}, subject to limitation by the breakdown voltage of the gate oxide. Another way is to choose the resistances of the bias circuitry to reduce R_T.

This work was done by Reuben Benumof and John A. Zoutendyk of The College of Staten Island for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Response of a MOSFET Circuit to a Cosmic-Ray Ion Track," Circle 32 on the TSP Request Card.* *NPO-17146*

★ ★ Technology Forecast ★ ★

Integrated Circuits

"Rapid increases in chip complexity are forcing manufacturers to reconsider the way they design circuitry. Designers can now put a hundred million devices on a single chip, which makes quality assurance a difficult task. It's virtually impossible to test such a complex device for every failure mode. I believe industry will address this problem in the future by designing circuits for testability.

Another important development for 1989 and beyond is the commercial introduction of the 'Z' focal plane architecture by the Irvine Sensors Corporation. This mosaic packaging scheme allows three-dimensional stacking of computer memory chips, providing a significant increase in electronics density over conventional planar techniques. The further development of low power CMOS analog and digital integrated circuits, massively parallel processors, and neural network architectures should enhance the usefulness of 'Z' technology."

Dr. Martin Buehler,
Senior Research Scientist and VLSI Technology Group Supervisor at NASA's Jet Propulsion Laboratory.

★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Detector Arrays for Infrared Astronomy

The status of a development program is reviewed.

A paper describes the status of a program for developing integrated infrared detectors for astronomy. The program covers a variety of detectors, including extrinsic silicon, extrinsic germanium, and indium antimonide devices with hybrid silicon multiplexers:

- A 32- by 32-element indium antimonide charge-coupled device has been evaluated in the laboratory and incorporated in an astronomical instrument for observations from the ground. The testing equipment and software for this device are being modified for a 58-by-62-element direct-readout (DRO) InSb array.
- Two-dimensional accumulation-mode Si:Bi charge-injection device arrays in 16-by-16 and 2-by-64 formats have been tested and used in astronomical applications.
- DRO Si:As arrays in a 10-by-64 format have been used in field tests, and astronomical images have been obtained from them.
- Two-dimensional back-illuminated Si:As blocked-impurity-band (BIB) arrays in a 10-by 50-element format are being designed and built. They will include switched field-effect transistor (FET) multiplexers modified to provide nondestructive readout of charge. Tests of dark current of a 10-element front-illuminated Si:As BIB array are underway.
- An investigation of the applicability of discrete Si:As solid-state photomultipliers will explore analytically and experimentally the nature of dark counts (which would limit sensitivity in a cooled telescope).
- To extend the spectral coverage of extrinsic silicon integrated arrays to 30 μm, arrays with Si:Sb detector material have been combined with a silicon DRO multiplexer.
- Ge:Ga detectors in 1-by-8 modules with switched FET readouts have been developed to explore the feasibility of adapting the technology of low-noise integrated arrays to long-wavelength extrinsic germanium detectors.

The paper notes that for arrays to reach the background noise limit in a cryogenic telescope, continued reductions in readout noise and dark current will be needed. The effects of impacts of energetic charged particles should be understood better so that the properties and operating points of devices can be optimized. Better understanding of the imaging properties and image-processing requirements of arrays is also needed.

This work was done by C. R. McCreight, M. E. McKelvey, J. H. Goebel, G. M. Anderson, and J. H. Lee of **Ames Research Center**. *Further information may be found in NASA TM-88344 [N87-24378/NSP], "Detector Arrays for Low-Background Space Infrared Astronomy."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 20]. Refer to ARC-11789.

Empirical Modeling of Single-Event Upset

Experimental data support a worst-case model.

An experimental study presents examples of the empirical modeling of single-event upset (SEU) in negatively-doped-source/drain metal-oxide-semiconductor (NMOS) static random-access memory (SRAM) cells. Viewed as a whole, the experimental data support the adoption of a simplified worst-case model in which the cross section for SEU by an ion above a threshold energy equals the area of the memory cell.

The study included three design iterations of a depletion-made-load, high-performance NMOS SRAM, with electrical-channel lengths of 2.5, 1.6, and 1.1 μm and gate-oxide thicknesses of 700, 400, and 250 Å, respectively. The depletion-mode, pullup-load devices were n-channel transistors maintained in the conducting state by connecting their source and gate nodes with polysilicon lines that were also connected to the drain node of each n-channel, enhancement-mode pulldown device. The SRAM chips of each design iteration contained 4,096 bits with 1,024 × 4 (1,024 4-bit words) architecture. Each bit was embodied in a six-transistor cell.

The circuit chips were exposed to energetic bromine, iron, and carbon ions at the Brookhaven National Laboratory tandem van de Graaff accelerator. The number of SEU's produced by the ions and the ion energies were recorded. All of these SEU data are extremely accurate, enabling the correlation of the measured SEU cross sections with geometrical areas within each memory cell. To achieve the desired degree of accuracy, the number of errors (SEU's) counted plus the ion energy selected for each data point are such that the experimental uncertainty (error bars) falls within the data points as drawn on plots of the SEU cross section as a function of the ion energy.

In a memory cell of the type tested, a penetrating ion of stopping power greater

than 35 MeV-cm^2/mg can cause SEU by striking virtually any region of the cell. This is manifested by the experimental data in which the SEU cross section per bit approaches the total area of the cell at such stopping powers. An NMOS memory cell has only one sensitive node. Therefore, SEU is apparently caused by charge collection at that sensitive node via diffusion from a high-stopping-power ion track anywhere in the cell.

For ions with energies near and above the threshold for SEU, upsets occur when the ion tracks intersect the charge-collecting junction connected to the sensitive node. For these lower-stopping-power events, the ionized charge is collected primarily by electric-field-aided drift, and the experimental values of the SEU cross section per bit can be correlated with geometrical features (i.e., areas of charge-collecting junctions) within a cell.

This work was done by John A. Zoutendyk, Lawrence S. Smith, George A. Soli, of Caltech; Peter Thieberger of Brookhaven National Laboratory; and Stephen L. Smith and Gregory E. Atwood of Intel Corp. for **NASA's Jet Propulsion Laboratory**. *To obtain copies of the reports, "SEU Modeling Verification of NMOS Depletion-Mode-Load SRAMS" and "Empirical Modeling of Single-Event Upset (SEU) in NMOS Depletion-Mode-Load Static RAM (SRAM) Chips," Circle 86 on the TSP Request Card.* NPO-16920

New Mode for Single-Event Upsets

Experimental data indicate a previously-unsuspected conduction path.

A brief report presents the theory and experimental data regarding a newly discovered mode for single-event upsets (SEU's) in complementary metal-oxide/semiconductor, static random-access memories (CMOS SRAM's). SEU cross sections larger than those expected from previously known modes had given rise to speculation regarding the additional mode, and subsequent cross-section measurements appear to confirm the speculation.

A CMOS SRAM cell includes a bistable circuit with two internal nodes, one of which is near the source-supply voltage while the other is near the drain-supply voltage, in the steady state. In each of the previously known modes of SEU, the charge collected from an ion track causes the affected internal node to be pulled to the polarity previously assigned to the other node by discharging or charging the gate of the inverter opposite the one crossed by the track. These events occur in the drain areas of the p- and n-channel transistors that are in the nonconducting (off) state only. The total cross section per bit for these types of SEU's is the sum of areas of the p^+ diffusion, n^+ diffusion and surrounding depletion regions of the drains.

According to the theory of the newly discovered mode, an ion track that passes through the inner-node diffusion (n^+) drain of an n-channel transistor in the conducting (on) state can bridge the vertical npn structure and thereby pull a node that is normally near the source-supply voltage toward the drain-supply voltage, causing the gate of the opposite inverter to charge up toward the drain-supply voltage. The cross section per bit due to this type of SEU should correspond to the n^+ diffusion area alone. The measured total SEU cross sections as functions of energy show plateaus, the differences between which do, indeed, correspond to the sizes of the cell features to which they are causally related.

This work was done by John A. Zoutendyk, Lawrence S. Smith, and George A. Soli of Caltech, and Roger Y. Lo of Intel Corp. for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Experimental Evidence for a New SEU Mode in a CMOS SRAM," Circle 98 on the TSP Request Card.*
NPO-17266

Electronic Systems

Hardware Techniques, and Processes

High-Capacity Aeronautical Satellite Communication System

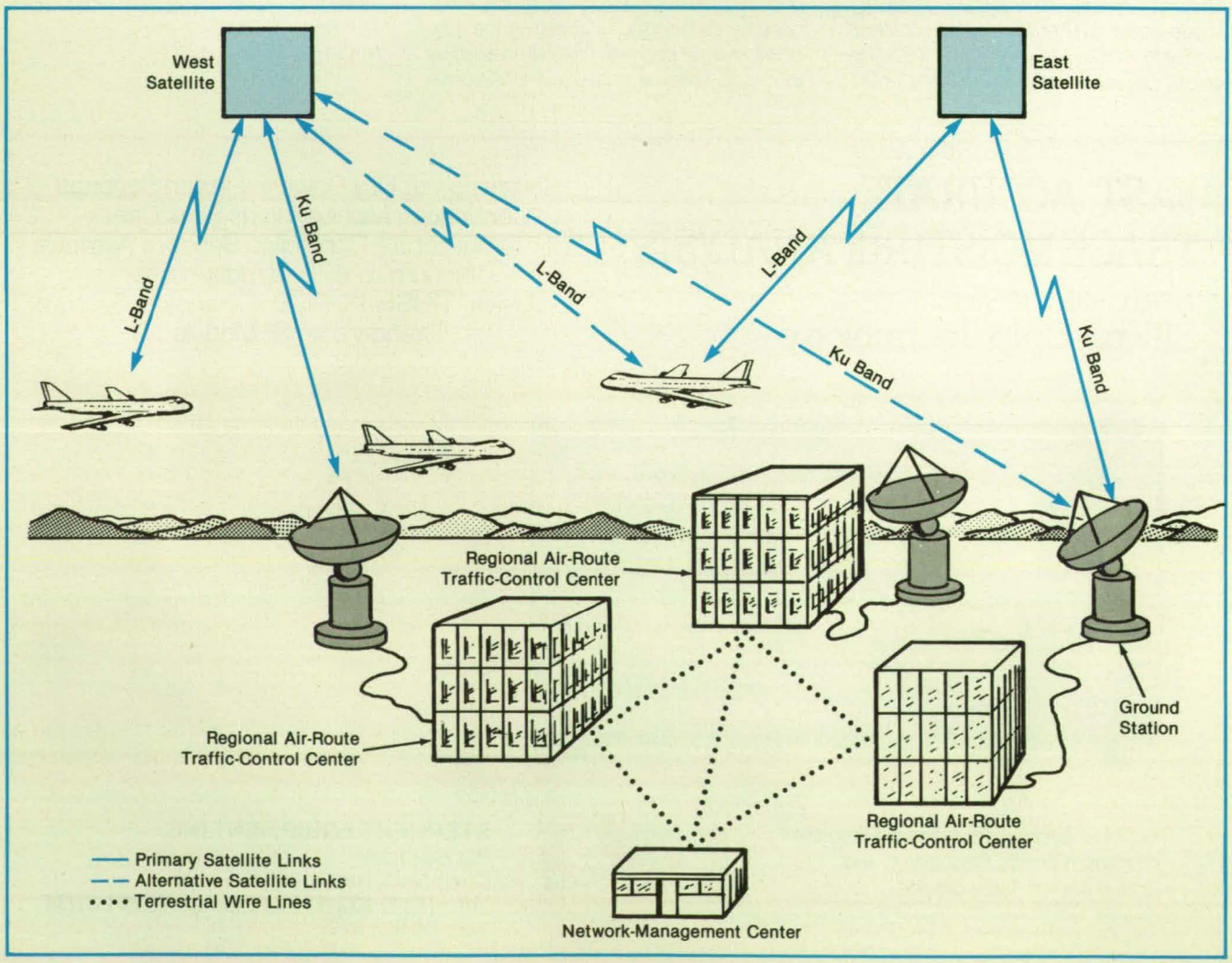
This system would provide safety-related communications to growing air traffic.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed high-capacity satellite communication system would serve as many as 86,000 aircraft. It would handle data and voice messages to and from commercial and general-aviation airplanes for automatic surveillance and air-traffic control in the contiguous United States. It would accommodate increasing air traffic while greatly reducing the load on terrestrial facilities and decreasing the amount of new construction.

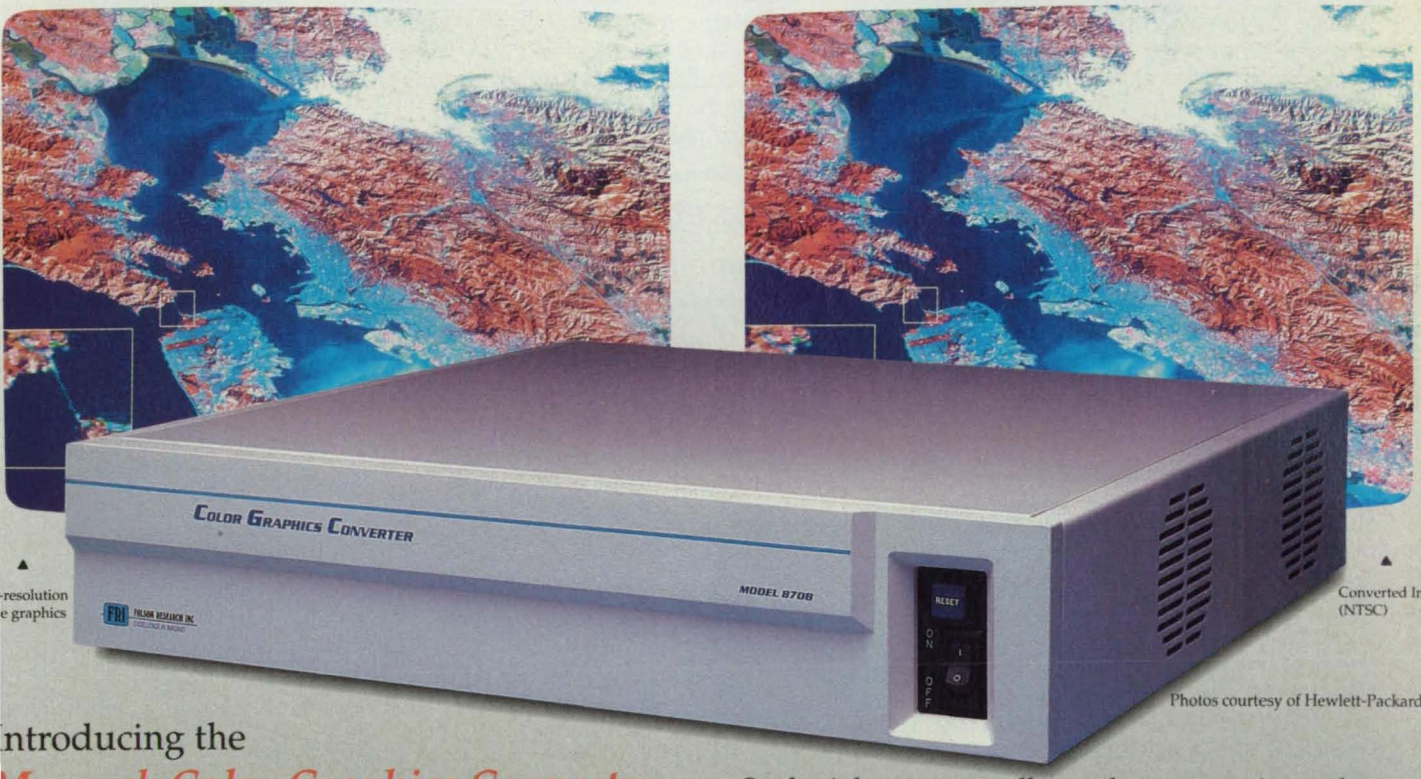
The system is primarily designed to serve aircraft en route; aircraft near terminals are best served by ground-based systems. The system would provide 5,093 forward communication channels (from the ground to aircraft) and 7,093 reverse channels (from aircraft to ground). This allocation of forward and reverse channels reflects anticipated communication traffic patterns.

Two satellites would be spaced 30° apart in geostationary orbit (see figure). Each would contain a small Ku-band antenna for communication between ground stations and the satellite and a large (15-m) deployable L-band antenna for communi-



East and West Satellites would relay messages from the ground to airplanes and from airplanes to the ground. The use of two satellites instead of one increases the availability of services and the reliability of the system.

Now You Can Get There, From Here



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Photos courtesy of Hewlett-Packard

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Circle Reader Action No. 386

cation between aircraft and the satellite. The L-band antennas would generate 31 and 28 beams, respectively. To enlarge the capacity of the system, the same frequencies would be reused in beams directed to widely-separated geographic areas. The large size of the L-band antenna increases frequency reuse and alleviates the burden on the airborne terminals.

To accommodate the limitations of general-aviation receivers, each beam would employ two transmitters: one producing 5 W of radio-frequency power for commercial aviation and another producing 18 W for general aviation. The Ku-band transmitter would produce 55 W.

The electronic equipment on the aircraft would require special provisions to accommodate the relative motion between aircraft and the satellites. For example, the combination of the aircraft-to-satellite range variation, multipath fading, and variation of antenna gain with aircraft orientation would cause the strength of a signal received at the satellite from an aircraft to vary over a few decibels. The varying signal would waste satellite power and increase intermodulation distortion. Accordingly, uplink power-control circuitry would be included in aircraft.

The frequency of the signals received and transmitted by the aircraft would be subject to large Doppler shifts. The resulting uncertainty in frequency could increase the time necessary to acquire air-to-ground transmissions and necessitate large intervals of frequency between channels, thereby wasting the spectrum. Accordingly, a frequency-compensation scheme is planned for the aircraft — one that would control frequency tightly without a stable and costly oscillator. A ground station would send corrections to account for the satellite-induced portion of the Doppler shift and for drift in the oscillator on board. The aircraft would perform regular frequency calibrations to reduce frequency uncertainties.

The antenna for a commercial aircraft would be a medium-gain phased array. For general aviation, a nearly omnidirectional antenna is proposed. More than one antenna may be needed.

The ground stations would be integrated with 20 air-traffic-control centers. The combined system would retain the major characteristics of the existing air-traffic-control system. The transition to the new satellite-based system — planned for the 1990's — should therefore be a smooth one.

This work was done by M. K. Sue, F. Davarian, and H. W. Chan of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 39 on the TSP Request Card.*
NPO-17234

Synthetic-Aperture Radar Processor for Large Drift Angle

Digital processing corrects for large range migration.

NASA's Jet Propulsion Laboratory, Pasadena, California

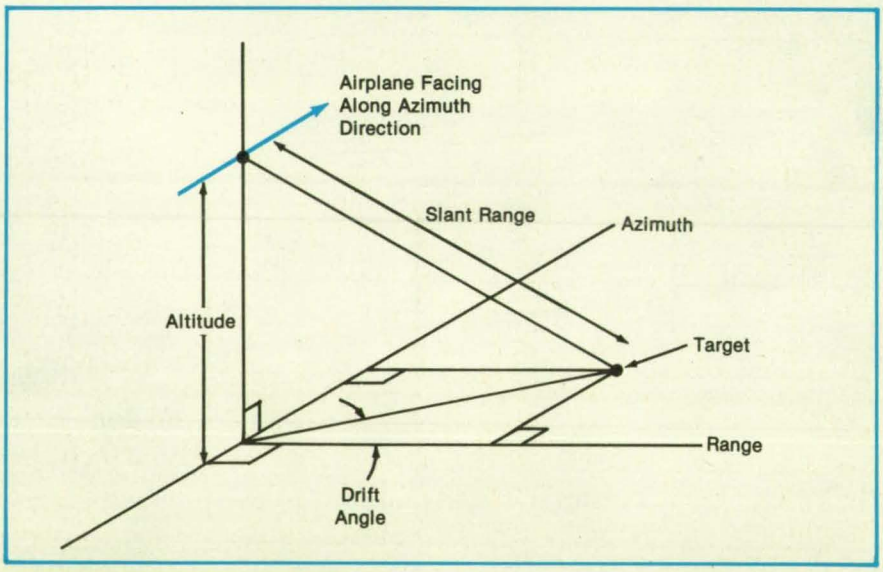
A digital signal-processing system makes images of terrain from synthetic-aperture-radar returns to an airplane flying at a large drift angle (see figure). The output of the system includes high-resolution images, four-look images, magnitude/phase-difference images, and "compressed," all-inclusive data sets. Magnitude/phase-difference images are produced by correlating images of the like polarizations (horizontal transmitted, horizontal received and vertical transmitted, vertical received). These images are useful for investigating the phase characteristics of targets in different polarizations.

To reduce the amount of data to be processed in the azimuth direction (with consequent loss of resolution deemed acceptable), a prefilter decimates the data by a factor of 8. A band-pass filter is applied before decimation to reduce the bandwidth of the data to avoid aliasing caused by subsampling.

The band-pass filter is centered at Doppler centroid frequency so that the maximum signal-to-noise ratio (SNR), which occurs along the boresight of the antenna, is preserved by the prefilter. The band-pass filter is implemented by first steering the data so that the centroid is at zero. A low-pass prefilter is then applied to the data. After prefiltering, the data are steered back so that the frequency band of the data is centered at the original Doppler centroid again: This step is necessary to enable the subsequent range-migration corrector to restore the trajectories of point targets.

The migration of a point target through different range bins increases with the drift angle. The restoration of the trajectory of a point target consists of two steps: First, the true range location of every azimuth picture element (pixel) in a particular range bin is determined. Next, the complex value of each azimuth pixel is estimated by interpolating the four pixels across the true range location to achieve a smoother frequency spectrum. During this process, it is assumed that the Doppler centroid frequency and rate of change of the Doppler frequency do not vary along the azimuth direction.

The interpolation is performed with a sinc [sin $(x)/x$] weighting function, which previous studies have shown to produce the least broadening of the main radiation lobe of the antenna. The azimuth pixels reconstructed by sinc interpolation appear smoother in the frequency domain and therefore produce sharper images in the time and space domains.



An **Airplane Flying at a Large Drift Angle** complicates the geometry and the processing of synthetic-aperture-radar returns.

This work was done by Yun-ling Lou, Howard A. Zebker, Quyen Dinh Nguyen, and Michael Y. Jin of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 65 on the TSP Request Card.*
NPO-17238

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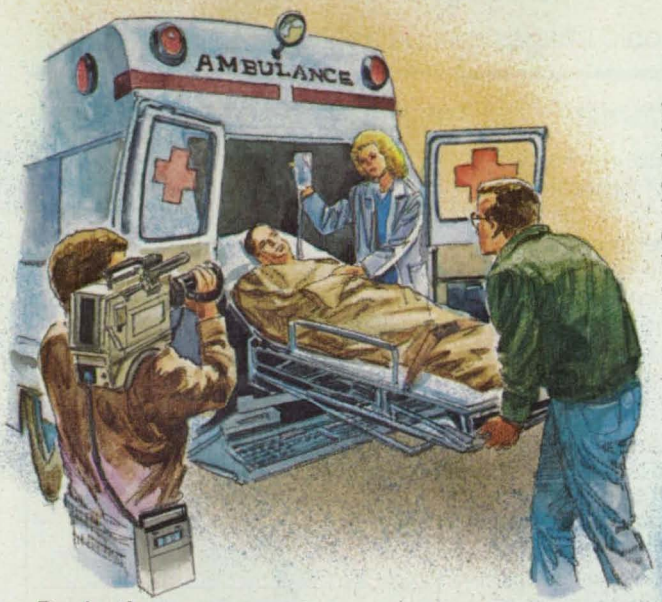

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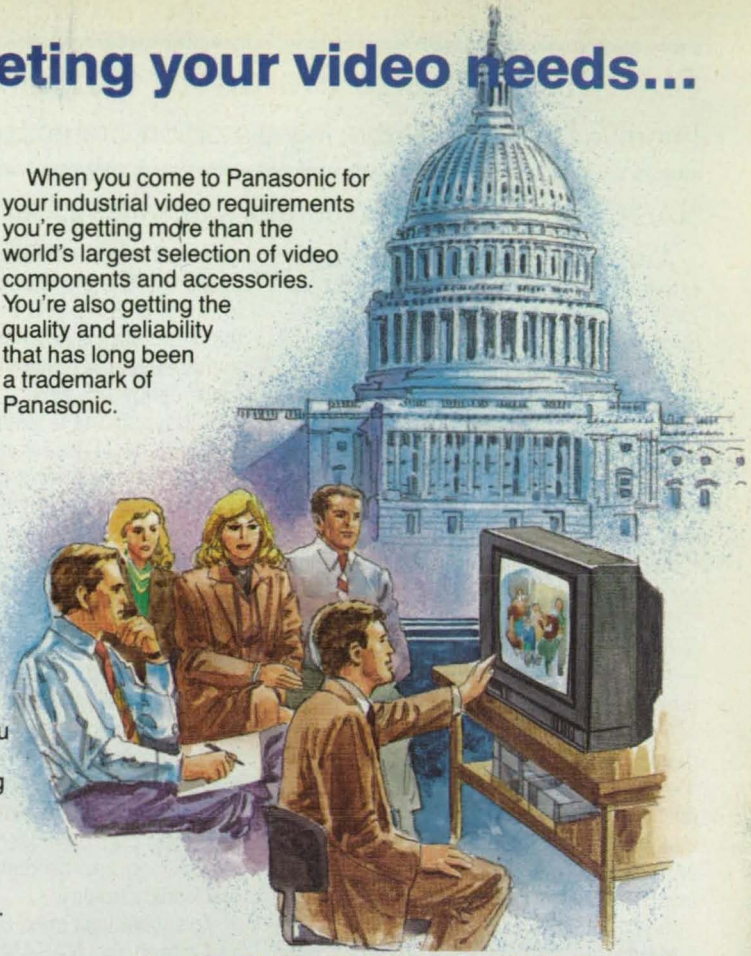

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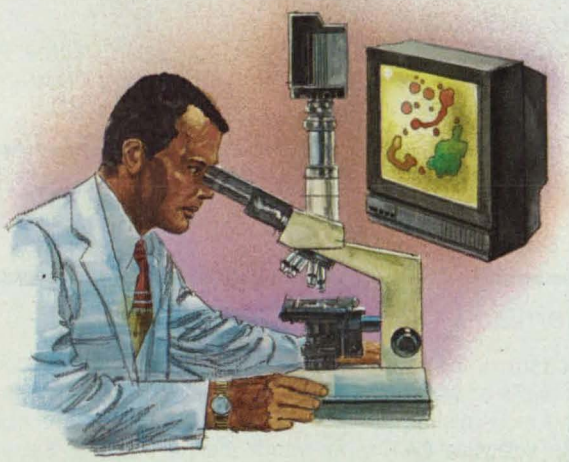

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Shifting of Image Fields for Better Stereoscopic TV Images

Improved high-resolution, low-distortion, stereoscopic images can be achieved electronically.

NASA's Jet Propulsion Laboratory, Pasadena, California

A concept for shifting the horizontal positions of TV image fields of a stereoscopic TV display would reduce stereoscopic depth distortion while increasing stereoscopic depth resolution of the images. The concept is applicable to a form of stereoscopic TV in which two views of a scene are presented by two video cameras to different fields of one monitor; for example, the odd field of the left camera to the odd lines of the monitor and the even field of the right camera to the even lines of the monitor.

In this scheme, a liquid-crystal stereoscopic viewer opens and closes light shutters in front of the viewer's eyes. The shutters are synchronized so that the left eye sees the screen when the odd lines of the monitor are illuminated, the right eye sees the lines when the even lines are illuminated. Thus, the left eye sees only the image from the left camera, the right eye sees only the image from the right camera, and the viewer perceives a composite three-dimensional image.

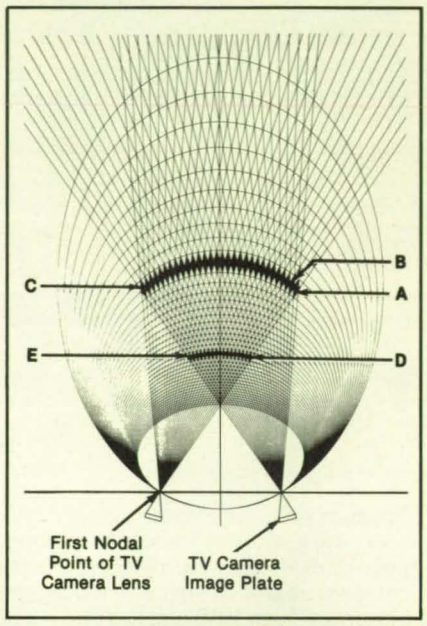
When the convergence angle of the cameras is set to give high depth resolution, the depth will be distorted. A horizontal meter stick, placed in the frontoparallel plane, which intersects the center of curve A-C in the figure, will appear to be convexly curved; that is, the ends away from the viewer. This occurs because curve A-C appears flat, and the ends of the meter stick are behind curve A-C while the center of the meter stick is not. A person attempting to maneuver the meter stick with a remote manipulator arm would have difficulty.

If the cameras are moved closer to the meter stick — to curve D-E, for example — the depth resolution is increased, and the depth distortion is reduced. The meter stick will appear less curved. However, curve D-E is difficult to view stereoscopically because the left and right images do not overlap on the television screen. For instance, point E is at the left edge of the view of the right camera and near the middle of the view of the left camera.

According to the concept, the view of the left camera can be shifted to the left, that of the right camera, to the right. The images can then be made to overlap, so that they can be observed comfortably. The shifting can be done by inexpensive electronic circuitry.

This work was done by Daniel B. Diner of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 1 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel. NASA Resident Office-JPL [see page 20]. Refer to NPO-17249.



The **Geometry of the Workspace** viewed by stereoscopic cameras is illustrated by the intersections of lines of sight to points on the image planes. Both curves A-C and D-E will appear flat, not curved, when viewed stereoscopically. (This figure is based on a computer-generated drawing by Peter German.)

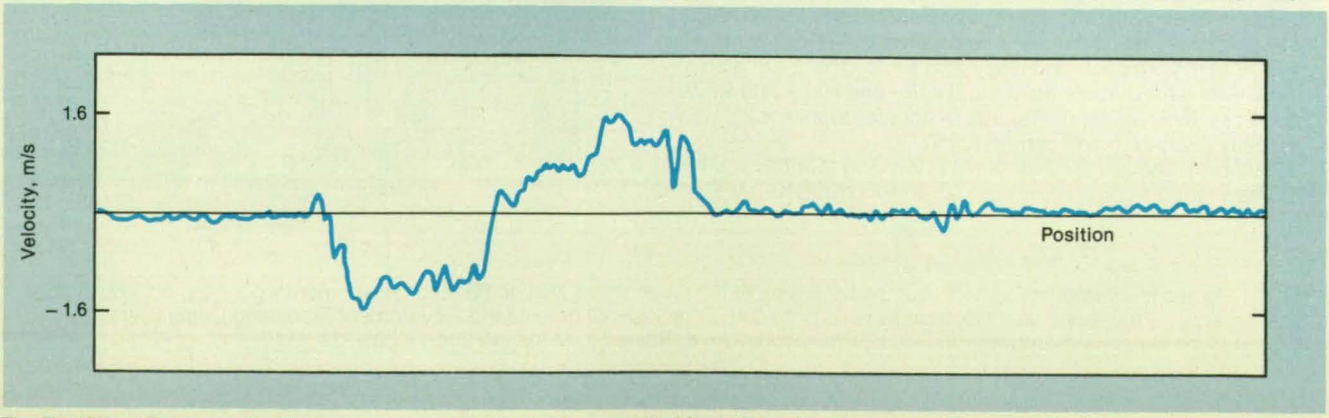
Radar Detects Ocean Surface Currents

An interferometric system uses reflections from ripples.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental airborne interferometric synthetic-aperture radar system measures the line-of-sight component of the velocity of ripples on the surface of the ocean. With the help of suitable assumptions about the relationships among the ripples, the larger waves or swells on which they occur, and the overall movement of the water, the component of velocity of the underlying surface current perpendicular to the path of the airplane can be deduced.

The radar detects ripples oriented perpendicularly to the radar line of sight and for which the projection of the surface wavelength along the line of sight equals



The **East/West Component** of the ocean-current velocity was computed from the radar returns at a 37° angle of incidence of the radar line of sight. The horizontal scale represents the position along a north/south flightpath about 11 km long.

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half the radar wavelength (Bragg reflection condition). The radar return is phase shifted by an amount proportional to the projection of the velocity of the ripples along the line of sight.

The system is essentially a synthetic-aperture radar equipped with two antennas separated by distance B along the direction of motion. The signals from the two antennas are processed separately into two images, which are then combined interferometrically to obtain maps of velocity. The motion of the ripples toward or away from the radar causes a phase difference, ϕ, between corresponding picture elements in the two images. This difference is proportional to the radial distance moved by a resolution element in the time required for the rear antenna to move to the position formerly occupied by the front antenna:

$$\phi = 2a\pi uB/\lambda v$$

where u = the line-of-sight component of the ripple velocity, λ = the radar wavelength, v = the velocity of the radar along the ground, and a = 2 if both antennas transmit and receive or 1 if one antenna transmits but both receive.

The experimental system, using λ = 24.5 cm, was tested aboard a CV-990 airplane with the two antennas separated by B = 18.5 m, with the rear antenna transmitting. Flying southward at an altitude of 26,000 ft (7.9 km) and a velocity of 461 kn (237 m/s), the system generated images of the San Francisco Bay region, showing peak east/west velocities of 1.6 m/s (see figure). (A velocity of 2.6 m/s was expected from tidal-current tables.)

Because the experimental images show no overall motion of the surface of the ocean (apart from the currents), it appears that each resolution element contains nearly-equal Bragg-component ripples traveling toward and away from the radar. Presumably, the two sets interact to form standing waves in the reference frame that moves with the current.

This work was done by R. M. Goldstein and H. A. Zebker of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 144 on the TSP Request Card.*
NPO-17192

Microwave Deflection Sensor

Movement is measured via the phase of the reflection.

Lyndon B. Johnson Space Center, Houston, Texas

A Doppler-radar instrument measures small deflections or vibrations of a reflecting surface. Acting as an interferometric micrometer, the instrument includes a combination of analog and digital circuits that measures the change in phase of the radar return due to the movement of the reflecting surface along the signal-propagation path. The radio-frequency portion of the instrument is a homodyne transceiver similar to inexpensive police speed-detecting radar sets.

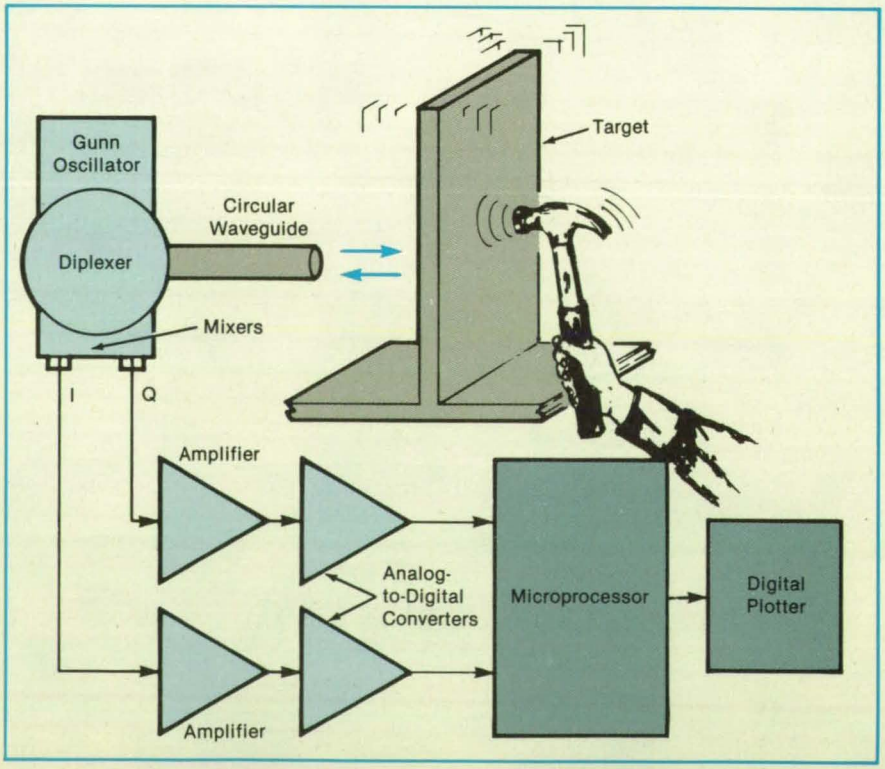
In the transceiver (see figure), a Gunn oscillator generates a carrier signal of the form $A\cos(\omega_c t)$, where A = amplitude, ω_c = the carrier angular frequency, and t = time. The oscillator output is fed to a turnstile diplexer, which converts most of its power to a circularly-polarized electromagnetic wave that is transmitted along a circular waveguide toward the target. To enable the measurement of the difference in phase between the transmitted and reflected signals, a small portion of the oscillator power is fed to one mixer [the in-phase (I) detector], and another small portion is shifted in phase by 90° and fed to another mixer [the quadrature (Q) detector].

The signal reflected from the target reenters the circular waveguide, travels along the waveguide to the turnstile diplexer, and is directed toward the I and Q detectors. At the detectors, the return signal has the form $B\cos(\omega_c t + 4\pi D/\lambda + \alpha)$, where B = amplitude, D = the distance to the target, λ = the wavelength of the carrier signal, and α is a constant component of the phase shift caused by the reflection from the target and propagation of the signal within the instrument.

The return signal is mixed with the oscillator signal in the I and Q detectors. The low-frequency components of the detector outputs are $C\cos(4\pi D/\lambda + \alpha)$ and $C\sin(4\pi D/\lambda + \alpha)$, respectively, where C = amplitude. These outputs are amplified, digitized, and sent to a microprocessor, which extracts the phase shift $4\pi D/\lambda + \alpha$. Once the initial value of D and α are determined in an initial calibration, the subsequent value of D can be determined from the measured phase shift. Even without calibration, the deflection (that is, the change in D) can be determined from the change in the phase shift.

The unambiguously measurable range of deflections can be increased beyond plus or minus half a wavelength by taking account of the inflection points of the processed signals to maintain a history of the total number of half-wave transitions. Fast Fourier transforms of the I and Q signals can be taken to obtain the frequency response of the target for analysis of its vibrations. A prototype of the instrument operating at 24 GHz can measure a maximum unambiguous deflection of $\lambda \approx 12$ mm with a resolution of less than 0.01 mm.

This work was done by Paul Shores, Herb Kobayashi, Phong Ngo, and C. L. Lichtenberg of **Johnson Space Center**. *No further documentation is available.*
MSC-20974



The **Microwave Deflection Sensor** includes a homodyne Doppler-radar transceiver and digital signal-processing circuitry to measure the change in phase shift as the target deflects.

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Flight testing is the most critical method by which Grumman Aircraft Systems evaluates tactical aircraft designs for both its planes and those from other aerospace companies. So, when Grumman puts these jets through series of strenuous test points, a recording system they rely on is from Gould.

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"The programmability of the Gould 3000 recorder provides greater productivity in a number of ways," says Tom Kastner, Grumman corporate manager of automated telemetry. "First, it allows faster, easier test setup with computer control of all parameter settings. "Second, it allows us to tie more resources together on-line. And, third, we can make fast changes to meet modifications in the flight plan. We're now able to make accurate value judgments and technical decisions to continue with our established flight plan or to modify it," concludes Kastner.

With the Gould 3000 recorder, Grumman has been able to expand its flight testing capabilities, speed development and delivery of aircraft, and reduce test costs. When Grumman relies on Gould to help them make a better airplane, it's not just a flight of fancy.

To get more information on this application or on the Gould 3000 Series recorders, call **1-800-GOULD-10**, or write Gould Inc., Test and Measurement, 3631 Perkins Avenue, Cleveland, OH 44114.

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Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Noise Performance of a Digital Tanlock Loop

A slight improvement over a sinusoidal phase-lock loop can be achieved.

A report discusses theoretical studies and numerical simulations of the performance of a digital tangent phase-lock loop (DTL) in the presence of noise. The performance is measured in terms of the phase-error variance and the mean time to skip cycle, both as a function of the input signal-to-noise ratio (SNR). For purposes of comparison, similar studies were conducted for a sinusoidal digital phase-lock loop like those in common use.

The analysis assumes a received signal $r(t)$ of the form

$$r(t) = A \sin [\omega_0 t + \theta(t)] + n(t)$$

where A is amplitude, t is time, ω_0 is the carrier angular frequency, θ is the signal phase, and n is the narrow-band Gaussian noise. The in-phase and quadrature components are sampled, yielding two sinusoidal components, $x(k)$ and $y(k)$ (for the kth sample), given by

$$x(k) = A \sin \phi(k) + n'(k) \text{ and}$$

$$y(k) = A \cos \phi(k) + n'(k)$$

where $\phi(k)$ is the phase error of the kth sample and n' is an independent Gaussian noise in the quadrature channel. The output $e(k)$ of the phase detector for the kth sample is then expressed as

$$e(k) = x(k)/y(k)$$

which would equal the tangent of the phase error in the absence of the noise.

The probability distribution function for $e(k)$ has been derived and is used to calculate the S-shaped curves that show the expectation (average) value of the phase-detector output as a function of the phase error for various signal-to-noise ratios. The noise in the tanlock phase-detector output has characteristics that depend heavily on the phase error and that are different from those of a sinusoidal phase detector. As a consequence, the S-curve analysis of the DTL is not as useful as it is in the sinusoidal case.

Numerical simulations of performance were carried out under various assumptions regarding the stochastic processes and filter equations involved. The mean times to skip cycle were found by calculating the mean numbers of cycles required to go from a phase error of zero to an error of $\pm 2\pi$.

Overall, the authors found that at an SNR of 5 or more, there is practically no difference in phase-error variance between the DTL and the sinusoidal loop, while at low to moderate SNR, the DTL exhibits a slightly smaller variance. At high SNR, the mean time to skip cycle of the DTL is less than that of the sinusoidal loop: this is a disadvantage. However, at low SNR, the difference in mean times to skip cycle is not significant. In consideration of the foregoing plus the extended linear range of the DTL, it appears to be somewhat advantageous to use the DTL where the input SNR is low to moderate.

This work was done by W. J. Hurd and C. A. Pomalaza-Raez of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Noise Performance of a Digital Tanlock Loop," Circle 61 on the TSP Request Card.*
NPO-16960

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Radar-Data-Processing System

A fast, complex, versatile system features reliable equipment and computer programs.

A report describes the radar data system at the NASA Western Aeronautical Test Range. This system provides real-time and recorded data about the flightpaths of research aircraft and the Space Shuttle. The system, called RADATS, processes data from three radars simultaneously; interacts with the system operator; enhances the data by introducing corrections and smoothing; controls the range, azimuth, and elevation of the radars; and automatically calibrates itself before and after missions.

The RADATS computer is based on a distributed-intelligence concept in which the input/output instructions are processed separately from other types of program instructions. The central processing unit (CPU) is linked to input/output processors on each interface channel. The CPU carries out 3 million instructions per second and processes 500,000 floating-point operations per second. It contains 768 kilobytes of error-correcting-code memory, expandable to 6 megabytes.

Built-in programs in the input/output processors autonomously control all input/output operations, including chained, multiple, direct-memory-access transfers of incoming and outgoing streams of data. The processors accomplish the transfers without interrupting the CPU except at the beginning and end of each input/output task and when new buffers with updated data are linked into a chain. The input/output processors transfer input and output data at rates up to 3.7 and 3 megabytes per second, respectively. Measurement input data and formatted output data are given priority in transfers because they run on fast cycles and must occur precisely on time.

The RADATS software is classified into three kinds of programs: utility, real-time, and calibration. The utility software includes programs to enter channel and frame formats, to reduce or compare data, and to perform geodetic computations and other computations associated with surveying and with the installation and calibration of equipment. The real-time software includes programs for such functions as the formatting and decoding of data, calculations of ranges and angles, digital filtering, calculations of state vectors, capture of real-time data for recording, and playback of recorded data. The calibration software includes programs that assure the accuracies of optical and radio-frequency tracking equipment.

At the operator console, the RADATS provides virtually all the information the operator needs for control before, during, and after a mission. It also gives the operator real-time answers about the effects of adjustments.

The equipment has exhibited exceptional reliability; the system has never failed to perform during mission support. The software has matured to become virtually trouble-free.

This work was done by Karl F. Anderson and John W. Wrin of **Ames Research Center** *and Robert James of GMD Systems. Further information may be found in NASA TM-88274 [N86-29884/NSP], "A Radar Data Processing and Enhancement System."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center *[see page 20].* *Refer to ARC-11782.*

★★★★★★★★ **Technology Forecast** ★★★★★★★★★

Communications

"We foresee within a decade the commercial inception of satellites with onboard switching of voice messages. This technology—to be tested by the Advanced Communications Technology Satellite (ACTS)—will in effect take the Master Earth Station and put it on the spacecraft. Such a system will allow very-small-aperture terminals (VSATs) to include both voice and data channels. As a result, use of VSATs will grow exponentially.

The development of this 'switchboard in the sky' will require frequency reuse and the creation of large, complex multibeam antennas. Phased-array feeds will be needed to minimize weight and power consumption and to enhance reliability. A baseband processor will serve as a start for onboard switching, and can be extended to answer the needs of several systems. For example, communication links will enable domestic satellites to connect to international satellites; with onboard processing, international calls could be readily routed by direct dialing."

Grady H. Stevens, Senior Systems Engineer at NASA's Lewis Research Center

★★★★★★★★★★★★★★★★★★★★★★★★

Approximations for Controls of Hereditary Systems

Convergence properties of controls, trajectories, and feedback kernels are analyzed.

A report discusses the use of factorization techniques to approximate the optimal feedback gains in the finite-time, linear-regulator/quadratic-cost-function problem of a system governed by retarded-functional-difference equations (RFDE's) with control delays. The author presents an approach to factorization based on a discretization of the state penalty that leads to a simple structure for the feedback control law.

The recently-developed factorization methods connect the problems of synthesis of controls, modeling of distributed systems, and approximation more tightly than does the traditional infinite-dimensional Riccati formalism. These methods rely heavily on the variation-of-constants formula for RFDE's and general Volterra factorization results for Hilbert-Schmidt operators. The feedback kernel is realized in terms of solutions to certain nonlinear Volterra equations (i.e., the factorization) associated with the fundamental matrix of RFDE's. The terms for control delays do not introduce any new conceptual difficulties with the factorization approach. Questions about the convergence of approximations of the feedback gains reduce to corresponding questions regarding the convergence of solutions to related factorization problems.

The author shows that if the cost function of the state in the regulator problem is a discrete sum with no integral term, then the associated factorization problem is solved by matrix inversion, and the exact feedback kernel can be defined in terms of the fundamental matrix solution, quadrature, and the solutions to finite-dimensional linear equations. Thus, an approximation scheme for the problem containing an integral state-penalty term can be developed by approximating this term by quadrature and solving exactly for the feedback kernel of the resulting discretized-state-cost problem. This approach, together with arguments relating to factorization, is used to establish $O(1/n)$ L_∞-convergence of the approximate feedback kernels in the case of time-varying control delay.

The analysis begins with the mathematical preliminaries, including a recapitulation of some previous relevant work on factorization — particularly certain aspects of the Volterra factorization and how they apply to the RFDE control problem. Next, the L_∞-convergence results for the feedback kernels, controls, and trajectories are presented. Instead of considering specific quadrature schemes approximating the state cost, all the results are proved with respect to a sequence of Borel measures satisfying certain convergence hypotheses. The principal mathematical tool at this stage of the analysis is a factorization lemma that asserts that the factorization problem is well posed in the space of integral operators with essentially bounded kernels.

The explicit form of the optimal feedback kernel associated with discrete state cost is then derived. The resulting approximation scheme developed from the cost discretizations is then used as an analytical tool to obtain further results regarding the feedback kernel. For example, using essentially matrix manipulation, a Wiener-Hopf integral equation for the optimal feedback kernel is derived and shown to be the control-delay generalization of a Wiener-Hopf equation previously derived for the feedback kernel via a maximum principle.

Two algorithms representing implementations of the basic approximation scheme are derived. In the time-invariant case, a

fast algorithm is derived by exploiting the near-Toeplitz structure of the system of equations that defines the feedback kernel. A simple numerical example is also presented.

This work was done by Mark H. Milman of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Approximating the Linear Quadratic Optimal Control Law for Hereditary Systems With Delays in the Control," Circle 37 on the TSP Request Card.*
NPO-17222

Repeated Transmissions in Mobile/Satellite Communications

Repetition would increase throughput and decrease delay.

A paper discusses the theoretical performance of a communication system for land-mobile stations with satellite relay using the ALOHA random-access protocol modified for repeated transmissions. Although the analysis is directed toward the NASA Mobile Satellite Experiment, its methods and conclusions also contribute to the general understanding of packet communications in fading channels.

In the pure ALOHA protocol, a land station transmits its message (which could be a packet of data) as soon as the message is generated. If the station does not receive a positive acknowledgement within a specified timeout interval, the station waits a random interval, then attempts transmission again. This process is repeated until transmission is successful. In a version called "slotted" ALOHA, all stations are synchronized so that all transmission attempts begin at the beginnings of time intervals (slots) of fixed duration τ. (The messages in pure ALOHA also have fixed duration τ, but there is no synchronization.)

The modified ALOHA protocol is based on the likelihood that in a fading channel, it will be necessary to repeat during many transmission attempts. Rather than waste some of the nearly-inevitable timeout and random waiting periods, the modified protocol specifies that at each transmission attempt, the message is to be repeated, without interruption, a fixed number of times. If the modified protocol is to be advantageous, then the reduction of message delay and increase in channel throughput, caused by the elimination of some of the timeout and random waiting, must exceed the increase in delay and loss of throughput due to the fixed repetition.

The analyses for the modified pure and slotted ALOHA channels are nearly identical. A general two-state mathematical model of the communication channel is used for the error process of the channel to account for the channel fading memory. The analysis includes the assumption of error-free acknowledgements and a fixed propagation delay between stations. Each message can be corrupted by collisions with other messages or by channel errors. If any of the identical messages in a repetition sequence are received without error, a positive acknowledgement is returned. The time between successive transmission attempts is assumed to be large enough so that the probability of successful reception of each attempt is independent and identical; that is, there is negligible channel memory between attempts.

Simulations were done for a pure ALOHA channel having the parameters of the reservation process of the Mobile Satellite Experiment. The numerical results for a moderately noisy channel with a packet error rate of 30 percent show that in terms of both the message delay and the channel throughput, it is best to transmit each message twice in a row at each attempt.

This work was done by Tsun-Yee Yan and Loren P. Clare of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Performance Analysis of the ALOHA Protocol With Replication in a Fading Channel for the Mobile Satellite Experiment," Circle 75 on the TSP Request Card.*
NPO-16705

Physical Sciences

Chopping-Wheel Optical Attenuator

A rotating star-shaped wheel provides adjustable attenuation independent of wavelength.

Goddard Space Flight Center, Greenbelt, Maryland

A star-shaped rotating chopping wheel provides adjustable time-averaged attenuation of a narrow beam of light without changing the length of the optical path or the spectral distribution of the light. The duty cycle or attenuation factor of the chopped beam is controlled by adjusting the radius at which the beam intersects the wheel (see figure). The attenuation factor is independent of wavelength.

The attenuation factors of variable neutral-density filters vary with wavelength. Such filters also affect the lengths of optical paths and can cause undesirable reflection, refraction, and scattering.

The chopping-wheel attenuator is useful in systems in which the chopping frequency is well above the frequency-response limits of the photodetectors that receive the chopped light. These include dc and low-pass-filtered detectors and such integrating detectors as photographic film and charge-coupled devices. The chopped beam produced by the attenuator can also be used in systems that use synchronous detection with lock-in amplifiers.

For a chopping wheel with uniformly-spaced symmetrical triangular blades, like the one shown in the figure, the radial position, r, of the beam as a function of transmission factor T is given by

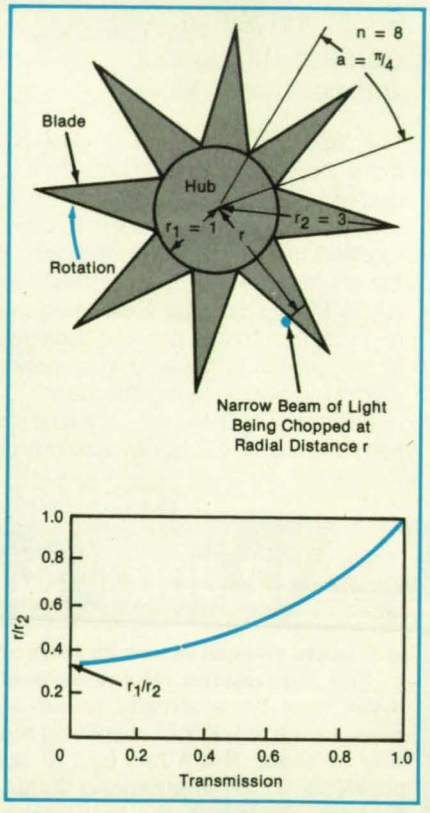
$$r(T) = r_2/\{[r_2/r_1 \sin(a/2) - 1/\tan(a/2)] \sin[a(1-T)/2] + \cos[a(1-T)/2]\}$$

where r_1 is the radius of the hub, r_2 is the radius at the tip of the blades, a is $2\pi/n$, and n is the number of blades. The inverse function, $T(r)$, has also been derived. A computer program in the BASIC language tabulates and graphs $r(T)$ for wheels with values of r_1, r_2, and n selected by the user.

The shape of the curve is affected strongly by the hub and tip radii and to a lesser extent by the number of blades. In practice, one designs a wheel by selecting the radii to obtain the general behavior desired and then choosing the number of blades for ease of fabrication and for chopping frequency. While it would be possible to calculate a blade shape that would provide a linear relation between radius and transmission, the edges of the blades would be curved and thus more difficult to fabricate.

A chopping-wheel attenuator has been used in an experiment to measure the angular dependence of light scattered from diffraction gratings. Scattering from a neutral-density filter would have altered the measured angular dependence. The 12-blade wheel used in this experiment was cut from sheet metal and painted flat black. Its attenuation properties agreed with the equation.

This work was done by Douglas B. Leviton of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13139



A Chopping-Wheel Attenuator provides variable time-averaged attenuation of a narrow beam of light by controlling the duty cycle of the chopped beam. The graph shows normalized radial position of the beam vs. time-averaged transmission (duty cycle) for the eight-pointed wheel.

Mathematical Model for Scattering From Mirrors

Additional terms account for the effects of particulate contamination.

NASA's Jet Propulsion Laboratory, Pasadena, California

A semiempirical mathematical model of the scattering of light from the surface of a mirror gives an improved account of the effects of particulate contamination. Models that treated only the scattering by microscopic irregularities in the surface gave bidirectional reflectance distribution functions (BRDF's) that differed from measured scattering intensities over some ranges of angles. Previous attempts to account for scattering by spheres and by dust on the surface also yielded unsatisfactory results.

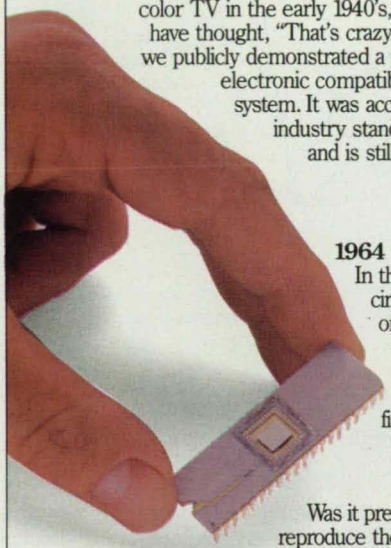
The bidirectional reflectance function, f_r, is given by

$$f_r = (2/\pi)(2\pi/\lambda)^3 F(\theta) W(P)$$

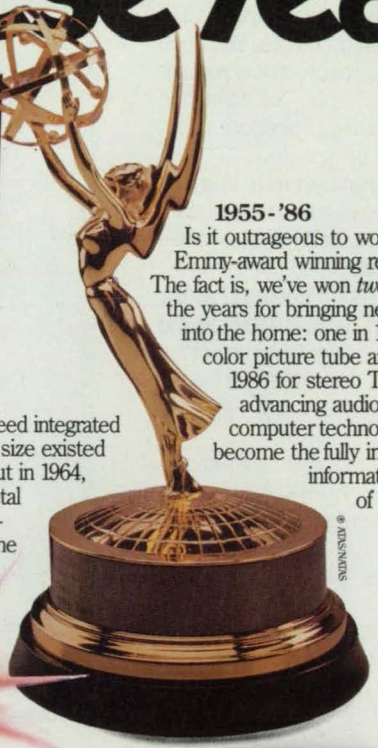
where λ is the wavelength of the light, $F(\theta)$ is an optical factor that depends on the polarization of the light [s (perpendicular to the plane of incidence) or p (parallel to the plane of incidence], $W(P)$ is the power spectrum of the surface-height distribution, $P = (2\pi/\lambda)(\beta - \beta_0)$, β is the direction cosine of the angle of incidence, and β_0 is the direction cosine of the angle of scattering.

Still Crazy After All These Years.

1946
When the David Sarnoff Research Center was working on color TV in the early 1940's, people may have thought, "That's crazy!" Yet, in '46 we publicly demonstrated a practical, all-electronic compatible color TV system. It was accepted as the industry standard in 1953, and is still used today.



1964
In the 1950's, the concept of low-power, high-speed integrated circuits a few thousandths of a square inch in size existed only in science fiction, and the laboratory. But in 1964, we introduced the first complementary metal oxide semiconducting chip. Then demonstrated its marketplace value by building the first CMOS 8-bit microprocessor.



1955 - '86
Is it outrageous to work with an Emmy-award winning research center? The fact is, we've won *two* Emmys over the years for bringing new technology into the home: one in 1955 for the tri-color picture tube and another in 1986 for stereo TV. Today, we're advancing audio, video and computer technologies that may become the fully integrated home information center of the future.

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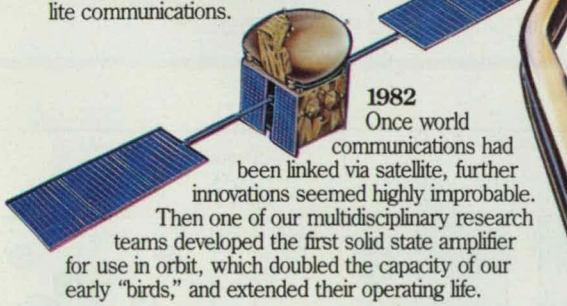
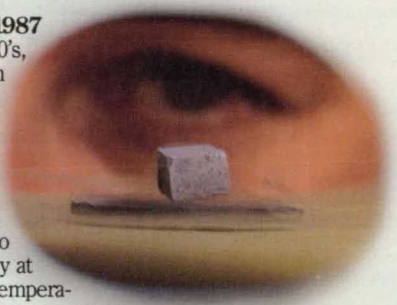
1986
Was it preposterous of us to try to reproduce the power of a room-sized laser in a smaller unit? No, we actually made our latest surface-emitting diode lasers smaller than the head of a pin. But what's really incredible are the opportunities they've opened for miniaturizing equipment in medicine, computing and satellite communications.



1982
Once world communications had been linked via satellite, further innovations seemed highly improbable. Then one of our multidisciplinary research teams developed the first solid state amplifier for use in orbit, which doubled the capacity of our early "birds," and extended their operating life.

1987
During the early 60's, we were a pioneer in superconductivity research, and the leader in developing commercial applications for superconducting wire which operated at extremely low temperatures. Modern superconductors have no resistance to electricity at twice the previous temperature and can levitate a magnet like the one shown here, but we're working on superconductive circuits that will operate at room temperature.



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Heads in the clouds, feet on the ground.

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Circle Reader Action No. 604

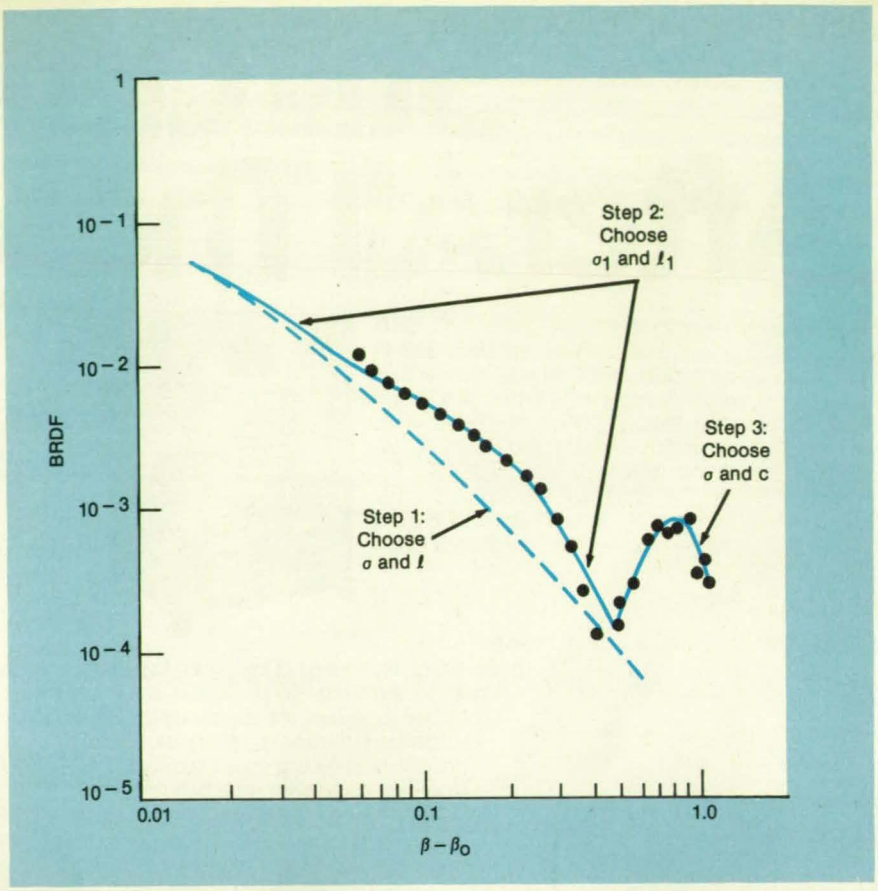
The power spectrum $W(P)$ is the Fourier transformation of the autocorrelation function of the composite surface-height distribution. It is expressed as a sum of Lorentzian and Gaussian functions:

$$W(P) = [2\sigma^2\ell/(1+P^2\ell^2)] + \pi^{1/2}\sigma_1^2\ell_1 \{\exp(-P_1^2\ell_1^2/4) + \gamma \exp[-(P-c)^2\ell_1^2/4]\}$$

The parameters $\sigma, \ell, \sigma_1, \ell_1, \gamma$, and c could be found by adjusting them simultaneously until they provide a least-squares best fit of $f(r)$ to scattering measurements. Because this is an iterative approach, it may require too much computer time. The following step-by-step curve-fitting procedure takes less time and works fairly well:

1. Using only the Lorentzian term [the first term in $W(P)$], choose σ and ℓ so that $f(r)$ approximates the experimental scattering data (see figure).
2. Add the Gaussian term centered at the origin [the second term in $W(P)$] to the equation obtained in step 1, and select the values of σ_1 and ℓ_1 that make f_r fit the experimental data at values of $\beta - \beta_0$ up to about 0.5.
3. Add the Gaussian term with shifted center [the third term in $W(P)$] to the equation obtained in step 2, selecting the values of γ and c that make f_r fit the peak in the experimental data at the larger values of $\beta - \beta_0$.

This work was done by Yaujen Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 129 on the TSP Request Card.* *NPO-17050*



A **Curve Is Fitted** to experimental data in three steps. Two of the parameters are found by trial and error at each step: This is simpler than trying to find all six parameters simultaneously and is almost as accurate.

Numerical Modeling of Two-Phase, Reactive Flows

Capabilities of several computational schemes are combined and enhanced.

Marshall Space Flight Center, Alabama

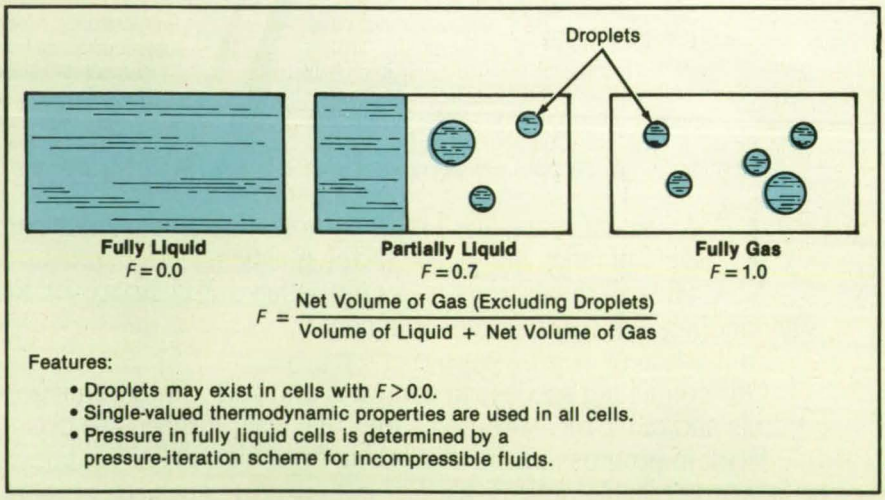
The Advanced Rocket Injector-Combustor Code (ARICC) is a computer program for the numerical simulation of two-phase flows of chemically reacting or nonreacting components. It can be applied to sprays of fuel in injectors and combustors; flows in heat exchangers, evaporators, and mass-diffusion systems; and two-dimensional or axisymmetric flows containing liquid or solid suspensions (e.g., coal slurries flowing in pipes).

Specialized computer codes had previously been developed, each to solve a specific type of fluid-dynamic problem, but no single code could treat all of the phenomena encountered in liquid/gas interactions. The capability of ARICC for the comprehensive modeling of many of these phenomena is due to the combination of the capabilities of several of the previous codes, including the following:

- The implicit-continuous-Eulerian (ICE) scheme and arbitrary-Lagrangian/Eulerian-Mesh treatment for all flow speeds from the CONCHAS-SPRAY code for reactive flows with fuel sprays;
- The equilibrium- and kinetic-chemistry models from CONCHAS-SPRAY;
- The fractional-volume-of-fluid technique from the SOLA-VOF algorithm for transient fluid flow (see figure); and
- The model for atomization from a program for the coaxial-injection combustion mode (CICM).

In addition, ARICC incorporates a new finite-droplet-displacement-volume description.

The resulting program is a two-dimen-



Active Cells in the finite-difference computational grid are distinguished by their values of the flag variable, F.

TEAM WORK

ARIANE PUTS SATELLITES INTO SPACE THAT SPEAK 27 LANGUAGES. AS INDUSTRIAL ARCHITECT AEROSPATIALE COOPERATES WITH 11 EUROPEAN COUNTRIES PROVIDING SPACE-AGE TECHNOLOGY AND MANAGEMENT SKILLS. WITH THE NUMBER OF SATELLITES LAUNCHED FOR AMERICAN COMPANIES, WE PROVE OUR CAPABILITY OF WORKING TOGETHER. AND AEROSPATIALE HAS BUILT MORE THAN 40 TECHNICALLY DIVERSIFIED SATELLITES, MANY OF THEM WITH AMERICAN PARTNERS. WORKING AND CREATING TOGETHER KEEPS US UP THERE. MEET THE TEAM.

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sional (or axisymmetric with swirl) code for real-time transient flows. Unlimited numbers of chemical species and of kinetic (slow) or equilibrium (fast) chemical reactions can be included. Discrete droplets of any size, with individual identities and properties, are described by use of the Monte Carlo numerical group technique and tracked in a Lagrangian fashion.

Cells that are inactive or that are fully liquid, partially liquid, or fully gaseous are distinguished from each other by a cell-flag/volume-of-fluid variable F (see figure). Gaseous portions of the cells satisfy the perfect-gas equation and are subjected to the normal ICE pressure-iteration technique for compressible flows (similar to the successive-overrelaxation scheme) to achieve convergence in satisfying the Navier-Stokes equations.

Liquid portions of the cells are given a constant temperature and density and go through an iteration scheme that enforces the conservation of volume. The portion of the liquid in each cell that contains a gas/liquid interface is periodically converted into droplets, according to the model for atomization, which calculates the mass-stripping rate and the mean drop radius as functions of the local conditions.

Droplets are then numerically diffused, convected, heated up, and evaporated according to empirical models. The dynamics of the droplets are fully coupled with the conditions of the fluid in each cell. Droplets, the paths of which lead them toward liquid surfaces, are "recondensed" back into the liquid. Chemical reactions and turbulent mixing take place only in the gaseous phase.

ARICC can be used in research for the development and verification of various physical models. In particular, models of atomization and of the breakup, coagulation, and deformation of droplets can be studied with rigorous description of the fluid-dynamic environment. Such mechanisms as the propagation, holding, and instabilities of flames and kinetic-chemistry models are also particularly suited for study with ARICC.

This work was done by Pak-Yan Liang of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 51 on the TSP Request Card. MFS-29027*

Thermographic Inspection of Coatings

A new use is proposed for existing equipment.

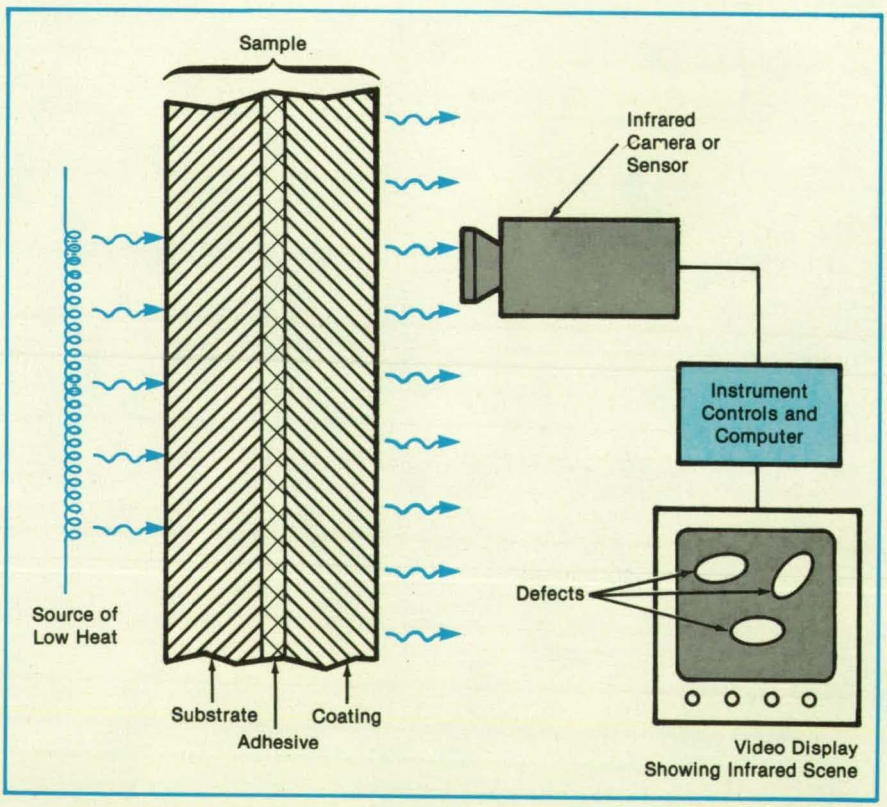
Marshall Space Flight Center, Alabama

The use of infrared thermography has been proposed for the inspection of some kinds of coatings — especially those intended to provide thermal protection. By the use of commercially-available infrared thermographic equipment, it may be possible to identify defects, including areas of poor adhesion.

A source of heat would be placed behind the sample to be inspected, and the sample would be viewed through the thermographic equipment (see figure). Depending on the specific thicknesses and types of materials in the sample, it may be preferable for the camera to view the coating side or the substrate side of the sample. Defects would be seen on the monitor as islands of different temperature. This inspection technique could be executed by remote scanning or by robotic scanning with automatic electronic detection of anomalies.

This work was done by W. A. Riehl and P. W. Hayes of United Technologies for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-28258.



A **Sample Heated Radiantly From Behind** would be viewed by infrared thermography. Defects in the coating would be visible at infrared wavelengths.

Beam Director for Optical Pyrometer

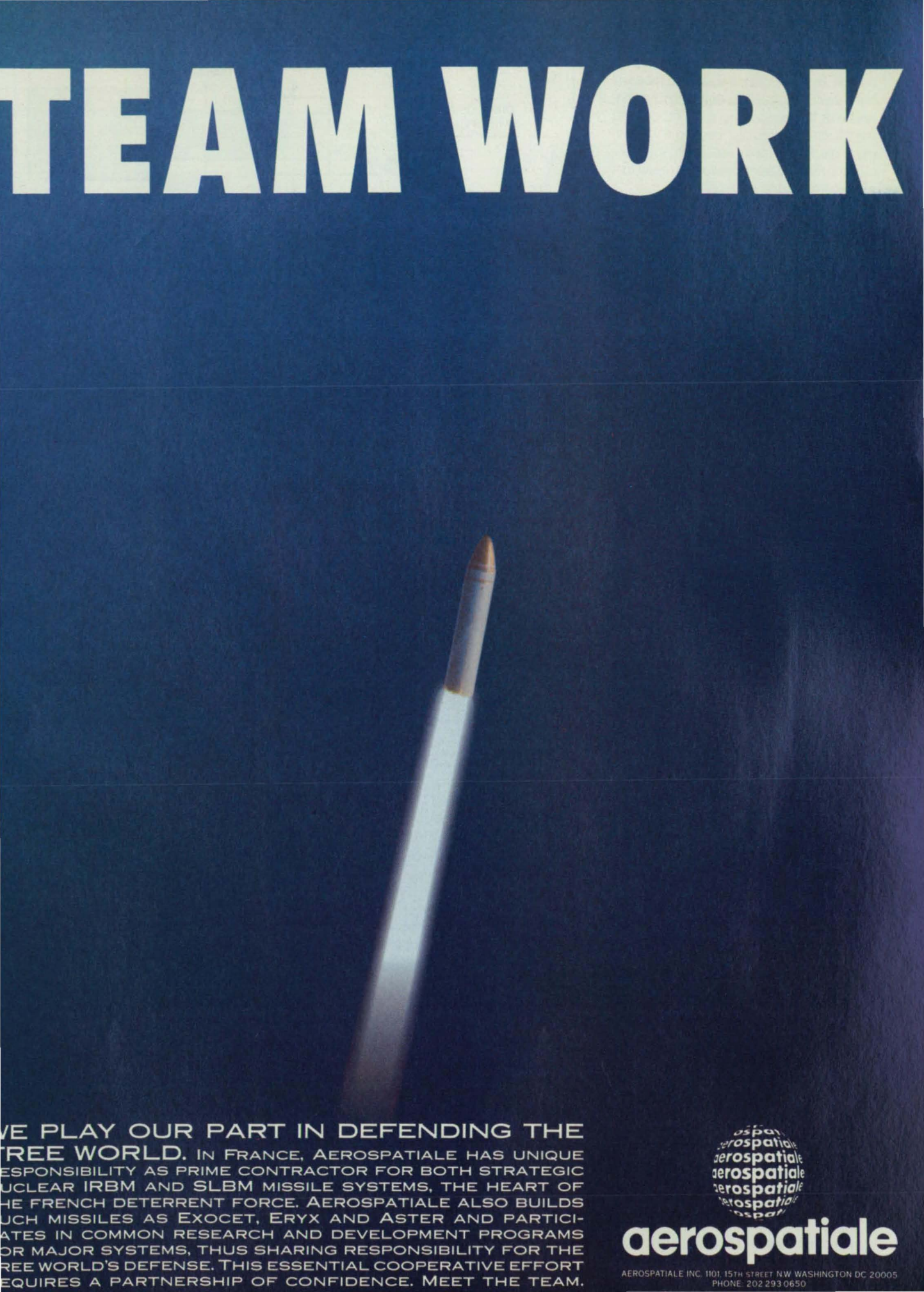
An instrument can "see" around bends.

Marshall Space Flight Center, Alabama

An optical-fiber pyrometer under development will observe fields of view as much as 31° off axis. The pyrometer was designed to measure the temperatures of moving turbine blades in turbopumps; the pump configuration prevented direct line-of-sight observation by the instrument.

The pyrometer will be fitted at its sensing tip with a sapphire cylinder that has a

TEAM WORK



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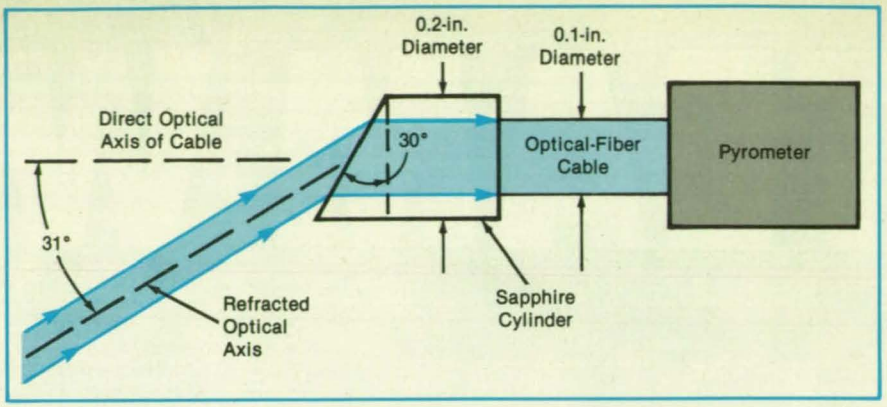
slanted end face (see figure). The sapphire withstands the high temperatures of turbopumps. By refraction, the slanted face will bend the viewing angle away from the centerline of the optical fibers. (A 31° bend is the maximum possible; beyond this viewing angle, total internal reflection would occur, and it would be necessary to resort to a more-complicated prism shape.)

This work was done by Lynn M. Wyett and Michael R. Randall of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29283



A Prismlike End Fitting Bends the Viewing Angle so that a pyrometer can "look" at an object off its axis. The angled face directs thermal radiation from the object into the optical-fiber cable along its axis.

Optical Sensor of High Gas Temperatures

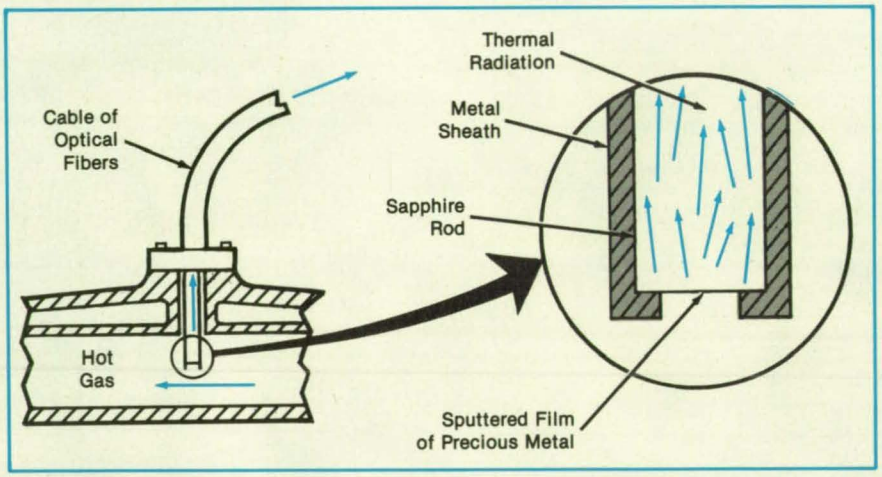
A contact pyrometer resists effects of heat, vibration, and moisture.

Marshall Space Flight Center, Alabama

An optical-fiber temperature sensor withstands hot engine-exhaust gases. The sensor is more reliable than thermocouples or resistance-temperature devices, the wires of which are subject to heat- and vibration-induced failure. It is more accurate than conventional pyrometers, which are prone to errors caused by shifts in the emissivities of gases with changes in temperature and composition.

The new sensor consists of a shielded sapphire rod with a sputtered layer of precious metal on its end (see figure). The metal layer acts as a blackbody. It emits radiation that has a known dependence of spectral distribution with the temperature of the metal and, consequently, with the temperature of the hot gas flowing over the metal. A fiber-optic cable carries the radiation from the sapphire rod to a remote photodetector.

This work was done by Arthur J. Hill of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.* *MFS-29316*



The **Optical-Fiber Sensor Projects** into a stream of hot gas. The temperature of the metal film on the tip of the sensor is essentially that of the gas. An optical-fiber cable conducts thermal radiation from the film to a photodetector.

Making Hydrogen Flames Visible

Invisible to the unaided eye, these flames can be seen with a special infrared camera.

Marshall Space Flight Center, Alabama

A modification of a standard, commercial video camera enables it to create images of hydrogen fires. Ordinarily, the silicon charge-coupled devices in the camera cannot detect radiation from such fires because burning hydrogen emits largely at nonvisible wavelengths; what little visible energy hydrogen fires emit is masked by ambient light.

The internal infrared-blocking filter is removed from the camera, and a filter with a 10-nm-wide passband at a wavelength of 950 nm is placed in front of the standard zoom lens. The filter passes infrared radiation from excited water vapor generated by burning hydrogen. The water vapor in the atmosphere absorbs solar radiation at the same wavelength. Thus, the iris of the camera can be opened fully without washing out the video image.

In a test, the modified camera detected a hydrogen fire caused by a ruptured nozzle tube on the Space Shuttle main engine. The fire could be observed only on the video image. The engine was shut down — and the leak corrected — before the engine was damaged.

This work was done by Joseph P. Brown of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29406

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Circle Reader Action No. 660

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

X-Ray-Scattering Measurements of Strain in PEEK

Internal stress is relieved by heating above the glass-transition temperature.

A report describes wide-angle x-ray scattering and differential scanning calorimetry of specimens of poly(etheretherketone) (PEEK) that have undergone various thermal treatments. Wide-angle x-ray scattering is particularly useful in determining distances between atoms, crystallinity, and such related microstructurally generated phenomena as thermal expansion and strain. The calorimetric measurements aid the interpretation of scattering measurements by enabling correlation with thermal effects.

Two materials were studied: (1) a low-molecular-weight PEEK powder synthesized in the laboratory and (2) high-molecular-weight commercial PEEK pellets. These materials were hot-pressed at 350 and 370 °C, respectively, then quenched to make thin amorphous (noncrystalline) films. The films were cold-crystallized at 176 °C for 24 hours, then annealed in flowing air at temperatures ranging from 230 to 319 °C. After annealing, the samples were cooled quickly to room temperature.

The wide-angle x-ray measurements were taken before and after the heat treatments. A diffractometer with copper-K_α radiation filtered through nickel was used to obtain scattering patterns in the reflection mode. The specimens were spun in the plane of the film during these measurements to average out the effects of orientations.

The scattering data suggest that thermal stresses are frozen into the material upon cooling: internal stresses apparently develop in the amorphous phase, causing the observed shifts in the amorphous-phase scattering peaks to smaller scattering angles, corresponding to larger spaces between molecular units. The low-molecular-weight material was found to be more susceptible to the creation of internal stresses.

To demonstrate that the observed shifts were indeed due to internal stresses in the amorphous phase, several films were subjected to differential scanning calorimetry before and after a treatment in which they were heated to just above the glass-transition temperature held for 5 minutes, then cooled slowly to room temperature. A stress-relief endotherm was observed in the untreated samples at the glass-transition temperature but not in the treated samples. In the treated samples, the x-ray-scattering measurements show that the molecules have relaxed to the equilibrium volume configuration.

This work was done by Peggy Cebe, Lynn E. Lowry, Shirley Y. Chung, Andre H. Yavrouian, and Amitava Gupta of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Wide Angle X-Ray Scattering of Strain in the Amorphous Phase of Poly(etheretherketone)," Circle 81 on the TSP Request Card.*
NPO-17097

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Circle Reader Action No. 550

Infrared Remote Sensing of the Martian Atmosphere

Distributions of temperature, dust, vapors, and condensates will be measured.

A report describes the design and intended uses of a developmental pressure-modulator infrared radiometer (PMIRR) that will be carried aboard the Mars Observer spacecraft. Applying remote-sensing techniques now used to study the atmosphere of the Earth, the PMIRR will take similar measurements from a polar orbit around Mars.

The PMIRR is a nine-channel atmospheric sounder that employs filter and pressure-modulation gas-correlation infrared radiometry. The nine channels share a common scanning mirror and a common primary telescope mirror. Mars and outer space will be viewed alternately at 800 Hz via a mirror chopper. The pressure-modulator cells for H_2O and CO_2 lie in the optical paths of channels and impart a 50-Hz amplitude modulation to the 800-Hz signal. Individual channels are defined by beam splitters, dichroic mirrors, band-pass filters, and the spectral responses of detectors.

The PMIRR will be used primarily to map the three-dimensional, time-dependent thermal structure of the atmosphere from the surface to a height of 80 km; the global, vertical, and temporal variations of the concentration of dust; the seasonal and spatial variations of the vertical distribution of water vapor; and the spatial and temporal variations of the concentrations of condensed water and carbon dioxide ice (that is, clouds).

Because of considerations of vertical and horizontal resolution, opacity, and sensitivity, the authors chose limb sounding as the primary mode of operation for the foregoing measurements. For measurements of thermal properties of the surface, nadir observations are used. Similar choices have been made in remote sensing of the Earth.

Gas-correlation spectroscopy is particularly appropriate for measurements of the atmosphere of Mars because radiation originating from airborne dust can be distinguished from that originating from the gas of interest. Pressure-modulation radiometry is a novel application of gas-correlation spectroscopy in which radiation from the emission lines of a specific constituent gas is detected during modulation of the pressure of the same gas in a cell placed in the optical path of the instrument. The transmission of the pressure-modulator cell (PMC), and hence the intensity of atmospheric radiation incident on the detector, varies at the frequency of modulation only near absorption spectral lines of the gas in question. Therefore, the signal at the modulation frequency, selected by electronic processing, quantifies emission in spectral regions in and near the absorption lines in the PMC, which match the emission lines of the same gas in the atmosphere.

The spectral response of a pressure-modulator radiometer (PMR) can be designed to fit the shapes of atmospheric spectral lines by varying the length, mean pressure, and depth of modulation of a cell. Once chosen, the length is fixed, but the pressure and the depth of modulation can be altered in flight.

In addition to its atmospheric observations, the PMIRR will also obtain data on the polar radiative balance, deposits of CO_2 frost, and thermal inertia of the surface. The PMIRR provides accurate surface brightness temperatures on the day and night sides in the wavelength range from 6.8 to 50 μm at high spatial resolution and with simultaneous measurements of broadband solar reflectance and the properties of the overlying atmosphere. The spectral response at 0.3 to 3.0 μm of the PMIRR solar channel encompasses over 97 percent of the incident solar flux, and its observations are used to construct hemispheric bidirectional reflection plots and determine albedos on a daily basis for the core regions of the north and south permanent caps.

This work was done by D. J. McCleese, J. T. Schofield, R. W. Zurek, J. V. Martonchik, R. D. Haskins, D. A. Paige, R. A. West, D. J. Diner, J. R. Locke, M. P. Chrisp, and W. Willis of Caltech; C. B. Leovy of the University of Washington; and F. W. Taylor of the University of Oxford for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Remote Sensing of the Atmosphere of Mars Using Infrared Pressure Modulation and Filter Radiometry," Circle 71 on the TSP Request Card.*
NPO-17353

Effect of Water on Permeation by Hydrogen

Water vapor in the working fluid equilibrates with permeability-reducing oxides in metal parts.

A report describes a study of the effects of water on the permeation of heater-head tubes by hydrogen in Stirling engines. The iron/nickel-based alloy CG-27 has been selected as the tube material because of its thermomechanical and chemical properties, one of which is its low permeability by hydrogen. However, the hydrogen working fluid can permeate even this alloy at the operating temperature range of 700 to 900 °C. The loss of hydrogen by permeation would necessitate frequent recharging of the engines.

The hydrogen can be doped with other gases to reduce permeability by an order of magnitude or more. The dopants are oxygen-bearing gases (e.g., carbon dioxide or water vapor) that form impermeable oxide layers on the insides of the heater-head tubes.

Experiments were performed to determine the minimum concentration of oxygen and/or oxygen-bearing gas that maintains an oxide coverage adequate for low permeability. Stirling test modules of heater-head tubes, previously oxidized by carbon dioxide-doped hydrogen, were placed in a furnace. The modules were filled with hydrogen having an oxygen content of 0 to 2,000 parts per million (ppm), and each was operated for about twenty 5-hour cycles. Between cycles, the modules were evacuated and refilled. Permeability was calculated from the pressure decline observed for each module.

The tests showed that 750 ppm or more of water are effective in maintaining stable, low permeability. Tests with total oxygen contents of 0, 265, 380, and 530 ppm equivalent water indicated that resistance to permeation cannot be reliably maintained at these lower levels, at which the chemical equilibrium among hydrogen, water (or oxygen-bearing gas), metal oxide, and metal is apparently tipped toward the reduction of the oxide and generation of water. As the oxide is chemically reduced, permeation by hydrogen increases until a new equilibrium is established. If the engine contains a mechanism for condensing the resulting water, the reduction may continue until all the oxide is consumed.

In an automotive Stirling engine, the operating temperature would be high enough to maintain 1,000 ppm of water vapor. Water that condenses when the engine is not running and cold would evaporate during operation and would be effective in maintaining the oxide coating. However, water could condense in the hydrogen-storage bottle of the engine, which is at the ambient temperature. It may therefore be necessary to heat the storage bottle to ensure sufficient water vapor in the engine.

This work was done by William A. Tomazic of **Lewis Research Center** *and David Hulligan of Sverdrup Technology, Inc. Further information may be found in NASA TM-88898[N87-16664/NSP], "Effect of Water on Hydrogen Permeability."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14648

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Computational Fluid Dynamics

"With advances in computer speed and memory will come the automation of computational fluid dynamics processes such as geometry definition and grid generation. Using high-speed workstations, the data that describes potential geometries will be cast in electronic format, eliminating the need to extract this information from blueprints or longitudinal cross-sections. Expert systems will be employed to create two- and three-dimensional grids with virtually no user interaction. The computer will evaluate criteria such as mesh distribution and curvature variation and then produce the right type of grid for the given geometry and flow conditions.

We also anticipate the emergence of a multidisciplinary approach to CFD over the next several years. By combining different fluid structures, for example, we'll solve problems related to wing vibration and propeller blade fluttering. Further down the road you'll see the combination of aerostructures and controls, with the potential for adding propulsion, electromagnetics, and many other disciplines."

Dr. Paul Kutler, Chief of the Fluid Dynamics Division at NASA's Ames Research Center

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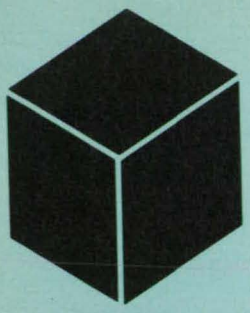

Materials

Fibers and Composites Derived From Silsesquioxanes

Shrinkage and voids are suppressed.

Lewis Research Center, Cleveland, Ohio

A method has been developed for the production of narrow ceramic fibers by melt spinning and for the production of ceramic composite materials by coating or infiltrating preforms or felts of such fibers. Silsesquioxanes having the general formula RSiO (where R is methyl, ethyl, propyl, vinyl, phenyl, or allyl) have been used to produce ceramic SiC powders and as components of resin sols for the impregnation of mats of fibers to form ceramic/matrix composites. Heretofore, the fabrication of composites by impregnation with solutions has required the removal of solvents, with the possibility of subsequent formation of voids and large shrinkages if removal is initially incomplete.

Ceramic fibers and matrices have also been fabricated from polysilane, polycarbosilane, and polysilazane precursors. However, syntheses with many steps are necessary to obtain these polymers, and the stoichiometric ratios of the resulting ceramics are difficult to control. By comparison, the silsesquioxanes are easily synthesized; some are produced commercially for use as additives in paints.

In the new method, silsesquioxane powders are blended to control the ratio of carbon to silicon. The blended powders are melted, and the excess silanol groups condense with the evolution of water. When the melt attains a suitable viscosity, it can be extruded into fibers through a die or drawn into fibers from the melt at a uniform rate. The fibers are then cured and heat treated.

The process for making composites begins with the winding of the fiber on a mandrel and the coating of the wound fiber with the silsesquioxane melt. After cooling, the fiber "prepreg" is cut into plies and stacked in a metal mold. The mold is inserted into a cold press, heated to a set temperature, and held under contact pressure during a specified time. Then the mold is heated to a new set temperature, a new specified pressure is applied, and the new pressure and temperature are maintained during a specified time. The laminate is then allowed to cool to room temperature before it is removed from the mold. The laminate is then cured and heat treated. The silsesquioxane melt can also be used to infiltrate a fiber preform.

The new method enables the easy fabrication of thermally stable fibers from inexpensive silsesquioxane precursors. Furthermore, the rheological properties of the melt and the composition of the fired ceramic can be controlled through the selection of the ratio of carbon to silicon in the starting polymer. Finally, the impregnation of fibers and preforms without solvent minimizes both the shrinkage and the formation of voids that result from the volatilization of trapped solvent.

This work was done by Frances I. Hurwitz, Lizbeth H. Hyatt, Lisa A. D'Amore, and Joy P. Gorecki of **Lewis Research Center**. *Further information may be found in NASA TM-89893 [N87-25432/NSP], "Silsesquioxanes as Precursors to Ceramic Composites."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center *[see page 20].* *Refer to LEW-14566.*

Improved Consolidation of Silicon Carbide

Careful processing increases strength.

Lewis Research Center, Cleveland, Ohio

Silicon carbide (SiC) and silicon nitride (Si_3N_4) are currently being evaluated as replacements for strategic metals in applications ranging from heat engines to industrial heat exchangers. The primary disadvantage of these materials is the inability to control fracture-generating flaws that lead to failures of components.

Agglomerates in the starting powders control the flexural strengths of sintered SiC test specimens. The dependence of mechanical properties upon these flaws obscures the effects of such important processing variables as compositions, sintering times, and sintering temperatures on the properties of sintered SiC. Slurry pressing was developed as a technique to avoid or eliminate agglomerates as sources of critical flaws.

The slurry-pressing die is shown schematically in the figure. The die works on a push-pull principle to draw the liquid out of the slurry. Liquid is pushed out through exhaust holes in the bottom plunger during pressing. Liquid is pulled out from the slurry through an exhaust hole in the top plunger attached to a vacuum pump. The other components of the die include filter paper to trap the powder, porous stainless-steel plates for uniform expulsion of liquid and forming, preformed bulk filter paper that swells during pressing to prevent leakage around the plunger, and an additional seal of porous polytetrafluoroethylene.

Colloidal techniques were used to improve the dispersion and suspension of SiC in water. In combination with slurry pressing, these techniques resulted in an increase in the strength of sintered SiC by 87 percent over that of SiC sintered after dry pressing. The improvement was due to reduced porosity (as shown by image analy-

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sis) and was reflected in improved densities of "green" (unheated) and sintered specimens. Smaller sizes of pores and reduced sizes of critical flaws also contributed to the increase in strength.

Thus, with careful colloidal control of the slurry, aqueous slurry pressing provides a means of consolidating ceramic powders to form simple to moderately complex shapes. The technique should be useful for making parts from particulate-, transformation-, and whisker-toughened ceramics as well as monolithic ceramics. It should also provide an avenue for the study of the many other variables that contribute to the reliability of current structural ceramics.

This work was done by Marc R. Freedman of **Lewis Research Center** *and Michael L. Millard of General Electric Co. Further information may be found in NASA TM-87243 [N86-24836/NSP], "Improved Consolidation of Silicon Carbide."*

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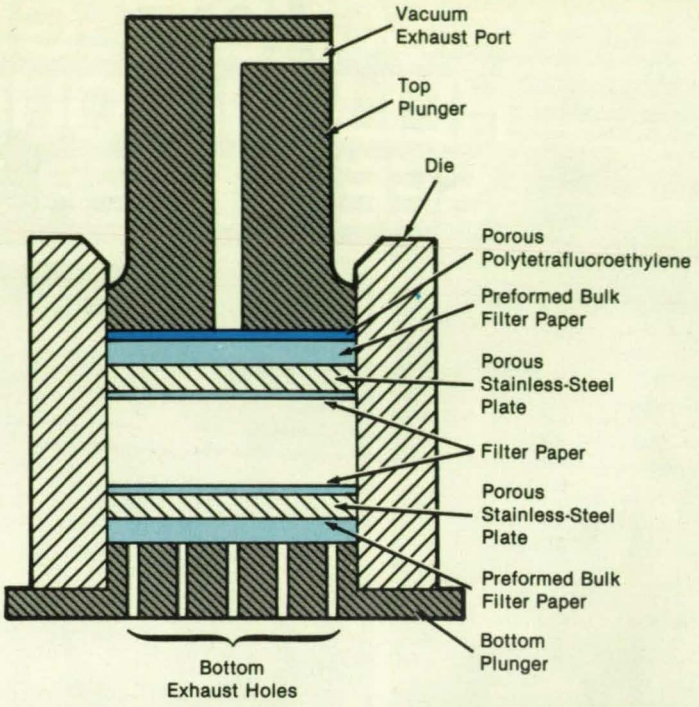
LEW-14681



The **Slurry-Pressing Die** presses and draws the liquid out of the slurry as it presses the slurry into the desired shape.

Centrifugation Would Purify Mercuric Iodide

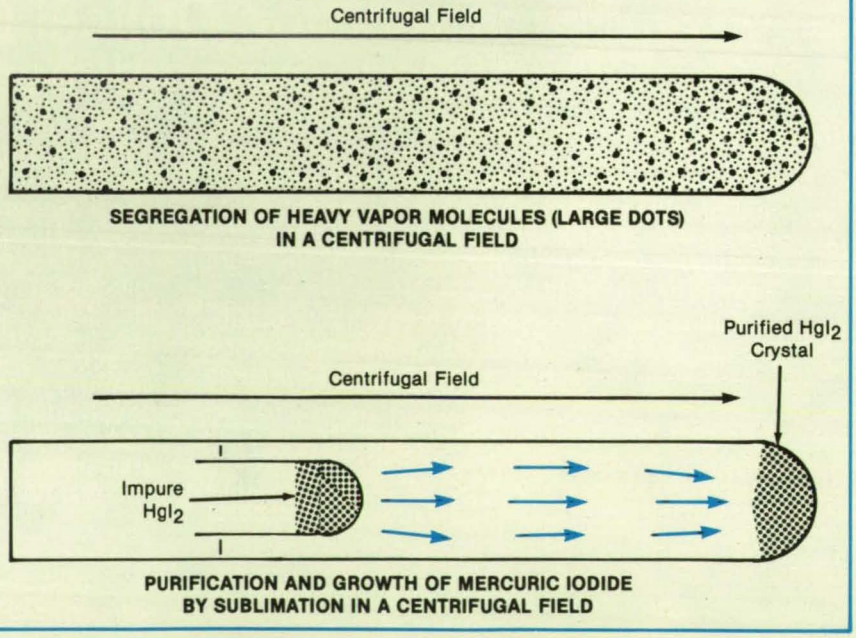
Vapor-deposition, solution, and melting/freezing methods are proposed.

NASA's Jet Propulsion Laboratory, Pasadena, California

Three proposed techniques for the purification of HgI_2 involve centrifugation. HgI_2, which is used in x-ray and γ-ray detectors, deteriorates gradually and exhibits less-than-optimum energy resolution; these deficiencies have been attributed in part to impurities, including deviations from stoichiometry.

In one technique for purification (see figure), impure HgI_2 would be sublimated at the inner end of a centrifuge tube. When the temperature is adjusted to give sufficient vapor pressure, the HgI_2 and the impurities would both be vaporized, but the heavier HgI_2 molecules would be preferentially sedimented at the outer end by the centrifugal force. When the vapor pressure of the HgI_2 at the outer end exceeds the equilibrium value, a crystal of HgI_2 would start to grow there. Because the lower-molecular-weight impurities would be concentrated by pressure equilibrium at the inner end, the recrystallized HgI_2 at the outer end would be purified considerably.

In the second technique, a saturated solution of HgI_2 in dimethyl sulfoxide would be centrifuged at a temperature somewhat above the saturation temperature. A crystal of HgI_2 would grow at the outer end of the centrifuge tube, and the lower-molecular-weight impurities would remain in solution.



In a **Centrifuge Tube**, the heavy molecules of HgI_2 would settle at the outer end in preference to the lighter impurity molecules.

In the third technique, molten mercuric iodide would be centrifuged until the impurities are concentrated at the inner end, then cooled while centrifugation continues to freeze the material in place. The purified material would be cut from the outer end.

This work was done by Paul J. Shlichta of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 47 on the TSP Request Card.*
NPO-16737

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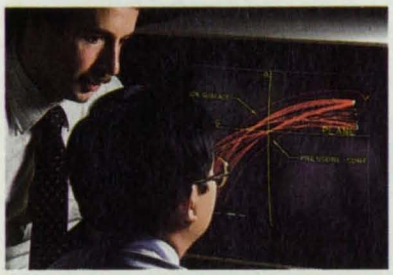

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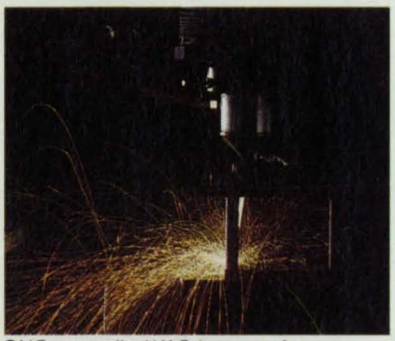

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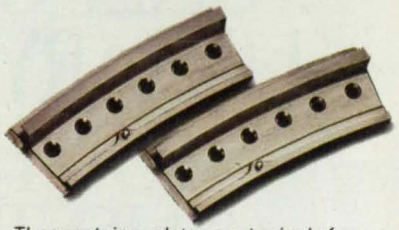

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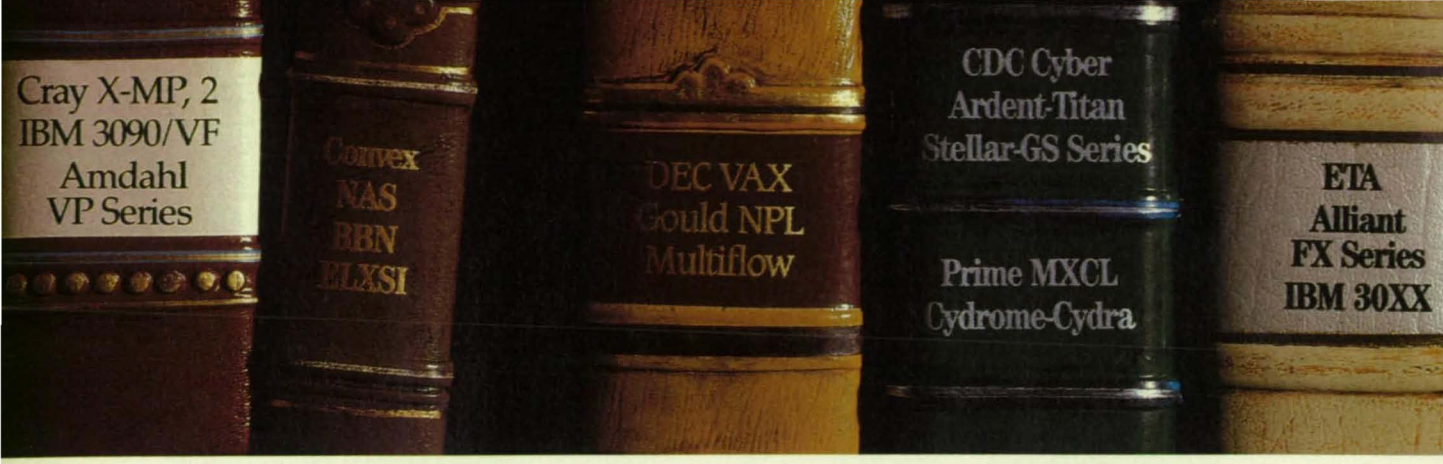

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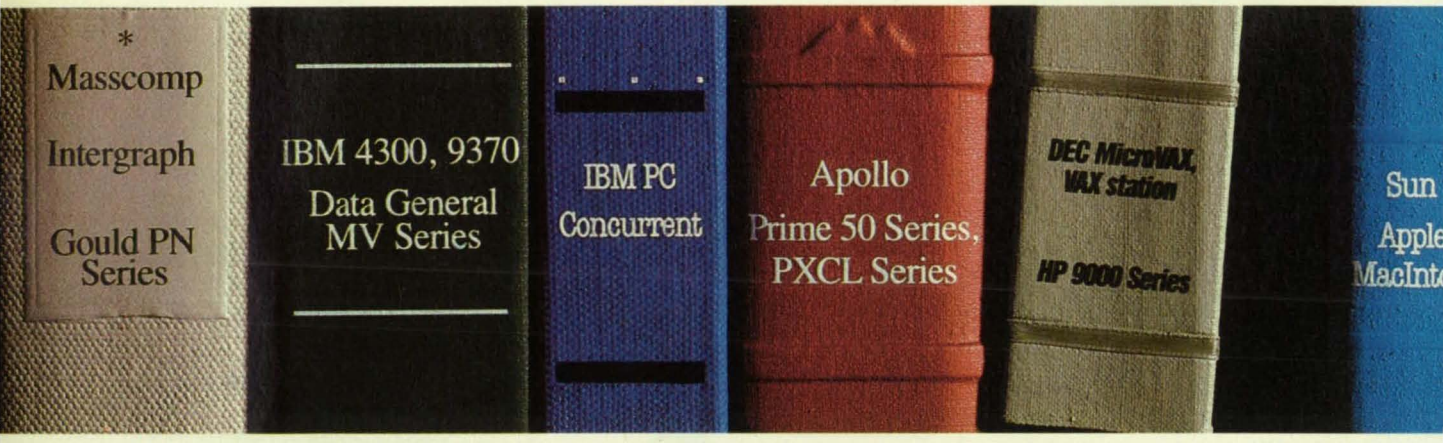

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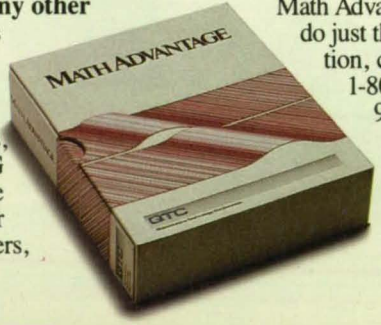

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Books and Reports

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Diffusion Analysis of Hydrogen-Desorption Measurements

The distribution of hydrogen in the metal explains the observed desorption rate.

A report describes the application of diffusion theory to the analysis of experimental data on the uptake and elimination of hydrogen in high-strength alloys at 25 °C; this study is part of a program aimed at understanding the embrittlement of metals by hydrogen. Two nickel-base alloys — René 41 and Waspaloy — and one ferrous alloy — 4340 steel — were studied. The desorption of hydrogen (measured in coulombs of H_2 desorbed as a function of time) is explained by the distribution of hydrogen in the metal; the "fast" hydrogen is apparently not due to the formation of hydrides on and below the surface, as had been proposed.

A theoretical section in the report reviews the diffusion equations governing the absorption and desorption of hydrogen. Solutions of the Fick law for diffusion along one dimension are employed for flat samples. The report also shows how the distribution of hydrogen in the sample can be determined by fitting theoretical curves for nonuniform or uniform distributions, or a combination thereof, to the measurements of the rates of desorption. Analytical and numerical solutions to the diffusion equations were in almost exact agreement. In the comparisons with experimental data, the analytical methods were used because of their greater computational speed and greater versatility.

Desorption measurements were made for two sets of charging conditions with a commercially-available corrosion-measurement console. Samples of the alloys were electrolytically charged with hydrogen in 0.1N H_2SO_4 at a current density of 1 mA/cm^2 for 4 h or at 60 mA/cm^2 for 1 h. Measurements were also taken on uncharged samples in 0.1N NaOH. The current due to hydrogen charging is the difference between the currents measured for the charged and uncharged samples.

For the nickel-base alloys, the distributions of hydrogen inferred from the desorption measurements after electrolytic charging conformed closely to those pre-

dicted by diffusion theory. Waspaloy samples were also charged atmospherically at a pressure of 5,000 psi (35 MPa); the inferred distribution of hydrogen was essentially the same as that obtained by electrolytic charging. The inferred distributions of hydrogen in 4340 steel electrolytically charged at 1 mA/cm^2 for 4 h were essentially uniform, a result not predicted by diffusion theory; this result may be explained by high permeability of the sample. The solubilities of hydrogen in all samples are higher at the higher charging rates. Future work will include the study of cylindrical samples, with the determination of the concentrations of both diffusable or mobile hydrogen and of trapped hydrogen.

This work was done by Merlin D. Danford of **Marshall Space Flight Center**. *Further information may be found in NASA TM-86531 [N86-15359/NSP], "The Application of Diffusion Theory to the Analysis of Hydrogen Desorption Data at 25 °C."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. The report is also available on microfiche at no charge. To obtain a microfiche copy, Circle 102 on the TSP Request Card.
MFS-27142

★ ★ Technology Forecast ★ ★

Ceramics

"A significant happening for the ceramics industry is the new phase of the Advanced Turbine Technology Applications Program, sponsored by the Department of Energy and managed by NASA's Lewis Research Center. Major resources are being allocated to ceramics suppliers to improve the quality, reproducibility, and fracture toughness of materials such as silicon carbide and silicon nitride. The program's ultimate goal is the development of a ceramic gas turbine engine that would offer better performance and fuel economy than conventional automotive engines at competitive costs. In the near term, however, the program will advance ceramic component technology in the U.S. and provide NASA with a technology base that could be applied to the fabrication of high-temperature parts for spacecraft."

Dr. Stanley R. Levine,
Ceramics Branch Chief,
NASA's Lewis Research Center

★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Strategic Materials for Superalloys

U.S. resources and reserves and possible substitutions are assessed.

A report discusses the status of strategic materials for superalloys in the United States. The report reviews trends in the development of superalloys, defines "strategic" materials, summarizes the state of U.S. resources and reserves, and discusses sources and availability of supplies. It reviews the results of the Conservation of Strategic Aerospace Materials (COSAM) program.

The report assigns the elemental constituents of superalloys to the following three groups according to increasing strategic value:

1. Aluminum, copper, molybdenum, magnesium, and iron;
2. Vanadium, rhenium, titanium, tungsten, silver, nickel, and gold; and
3. Tantalum, chromium, platinum, niobium, manganese, and cobalt.

Superalloys are the major materials of construction for high-temperature gas-turbine engines for both military and commercial aircraft. However, for the superalloy industry to thrive in the United States, there must be a readily available supply of the alloying ingredients. In the ideal situation, mining companies in the United States would be the primary suppliers to the alloy producers. Unfortunately, the United States has no ample reserves and resources of some of the ingredients and over the years has become increasingly dependent on foreign sources.

As a result of the COSAM program, however, technology was established for the substitution of other ingredients for strategic materials in nickel-base superalloys. This is especially true for cobalt; the physical metallurgy of low- and zero-cobalt alloys was characterized in terms of composition, microstructure, heat treating, and thermomechanical processing. Similar studies were done for tantalum and, less extensively, for niobium. In continuing research, iron and nickel aluminides, metal-matrix composites, and intermetallic-matrix composites have shown promise as potential replacements for superalloys containing cobalt, tantalum, niobium, and chromium.

This work was done by Joseph R. Stephens of **Lewis Research Center**. *Further information may be found in NASA TM-89866 [N87-21077], "Superalloy Resources — Supply and Availability."*

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LEW-14665

Computer Programs

62 SINDA—Systems Improved Numerical Differencing Analyzer

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Mechanics

SINDA — Systems Improved Numerical Differencing Analyzer

The capability to model fluid flow is added.

The Systems Improved Numerical Differencing Analyzer (SINDA) is a software system developed to solve physical problems governed by diffusion-type equations that can be mathematically modeled by lumped-parameter representations. The system is most widely used as a general thermal analyzer with resistor-and-capacitor-network representations. However, it can be adapted to a wide range of problems represented by Fourier, Poisson, Laplace, or other differential equations.

SINDA can solve numerically almost any set of ordinary differential equations, which may be used to represent the transient behavior of a lumped-parameter system, or any set of nonlinear algebraic equations, which might represent the steady-state conditions of a physical system. FLUINT, the FLUid INTegrator, is an advanced, one-dimensional fluid-analysis program that solves the equations of arbitrary fluid-flow networks. This release of SINDA85/FLUINT is to replace the thermal-only version of SINDA85.

For flexibility, SINDA offers a number of numerical solution techniques from which the user can choose. These include such finite-difference formulations of the explicit method as the forward-difference explicit approximation, the DuFort-Frankel, exponential, and alternating-direction approximations. Also included are such formulations of the implicit method as the backward-difference implicit and Crank-Nicolson approximations. The practical analysis of many physical problems, particularly thermal-analysis problems, can be achieved readily with the SINDA system.

The SINDA system consists mainly of a preprocessor and a library of subroutines. The SINDA preprocessor accepts pro-

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grams written in the SINDA language and converts them into standard FORTRAN programs. The SINDA language is designed for working with lumped-parameter representations and finite-difference solution techniques. The SINDA library consists of a large number of prewritten FORTRAN subroutines that perform a variety of commonly needed actions. The user can call these subroutines from their SINDA language program, thus greatly reducing the programming effort required to solve many problems. Most of the subroutines in the SINDA library were developed for use in solving thermal-analysis problems. As a thermal analyzer, SINDA can handle such interrelated complex phenomena as sublimation, diffuse radiation within enclosures, transport delay effects, sensitivity analysis, and thermal-network error correction.

SINDA can easily account for pumps, valves, and heat exchangers during a thermal analysis. The user-written SINDA language program determines the input data required and the information to be produced as output by the program. A pressure/flow analysis of a system containing an arbitrary tube network can be performed simultaneously with the thermal analysis during transient or steady-state solutions. This enables the inclusion of the mutual influences of thermal and fluid problems in the analysis. This fluid-network-analysis capability is called FLUINT.

SINDA is available by license for a period of 10 years to approved licensees. The licensed program product includes the source code and supporting documentation. Additional documentation may be purchased separately at any time.

SINDA is written in FORTRAN and Assembler. The program is available in three versions: CDC, DEC VAX, and UNIVAC. The CDC version has been implemented on a CDC CYBER 175 computer operating under NOS with a central-memory requirement at approximately 175K (octal) of 60-bit words. The UNIVAC version has been implemented on a UNIVAC 1100-series computer operating under EXEC 8 with a problem-dependent central-memory requirement not exceeding 65K of 36-bit words. The VAX version has been implemented on a DEC VAX-series computer operating under VMS. SINDA was developed in 1971, and fluid capability was added to it in 1975. The CDC version was last updated in 1984; the UNIVAC version, in 1985; and the VAX version, in 1988.

This program was written by Steve J. Damico of Lockheed Engineering and Management Services Co., Inc., for **Johnson Space Center**. *For further information, Circle 10 on the TSP Request Card.*
MSC-20891

★ ★ Technology Forecast ★ ★

Image Processing

"Speed is key in image processing today. Companies are tackling problems involving larger databases and higher data rates, and are looking for ways to quickly visualize the massive amounts of information being generated. As a result, there's going to be a great deal of activity over the coming year in development of software to implement visualization and image computing algorithms in larger machines, such as parallel processors and vectorized processors.

At JPL, we want to speed up the processing of multispectral and imaging spectrometer data. These are data types that produce a large number of spectral bands. Each pixel in an image may be represented by up to three hundred individual samples across the spectrum. In 1989, we plan to procure a state-of-the-art supercomputer to handle these enormous data sets."

Dr. Ray J. Wall,
Manager of the Image Processing Applications and Development Section at NASA's Jet Propulsion Laboratory

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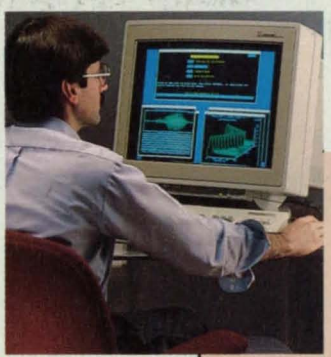

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Mechanics

Crash-Energy-Absorbing Composite Subfloor Structure

A weighted-sum method accurately predicts the energy-absorption capability.

Langley Research Center, Hampton, Virginia

A simple method of predicting the energy-absorption capability of a composite subfloor beam structure has been developed. The method is based upon the weighted sum of the energy-absorption capabilities of constituent elements of a subfloor beam.

The subfloor beam structure of a helicopter is composed of a grillwork of longitudinal and transverse beams. Noncrash loads carried by the beam structure typically consist of reaction loads from the fuselage skin, frames, bulkheads, and seats. Energy is absorbed in a helicopter during a crash primarily by controlled stroking of the landing gear and subsequent crushing of the subfloor beam structure. This beam structure typically consists of integrally stiffened, honeycomb-sandwich, unstiffened, or sine-wave beams.

In this study, the subfloor beam structure was used to describe and verify the method of predicting the energy-absorption capabilities of structural elements. It was hypothesized that the crash-energy-absorption capability of a structural element is the weighted sum of the energy-absorption capabilities of its characteristic elements. This hypothesis assumes that the structure progressively crushes before catastrophic failure.

The constituent elements of the beam can be either straight or curved sections. Tube specimens with circular or square cross sections were used in this study to determine the energy-absorption capabilities of the characteristic elements of the beams. Empirical data on the absorption of energy in circular- and square-cross-section tube specimens were used to make predictions. The procedure was demonstrated on three kinds of subfloor beams (see table). The measurements and predictions agreed within 7 percent in all three cases. This procedure is general and applicable to a wide range of subfloor beam structures.

Description of Specimen	Energy-Absorption Capability	
	Predicted (N-m/g)	Experimental (N-m/g)
Graphite/Epoxy Sine-Wave Beam	56	54
Polymer/Epoxy, Circular-Cross-Section-Tube-Stiffened Beam	30	28
Graphite/Epoxy, Rectangular-Cross-Section-Tube-Stiffened Beam	41	42

Weighted-Sum Predictions of crash-energy-absorption capabilities are compared with measured values.

This work was done by Gary L. Farley of the U.S. Army Aviation Research and Technology Activity for **Langley Research Center**. *For further information, Circle 18 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-13697.

Collecting Hypervelocity Particles Intact

Particles are stopped in soft materials.

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have been conducted recently to develop targets that will capture micrometeorites, dust, and other small particles in outer space traveling at speeds of several kilometers per second. A principal criterion for such a target is that it must stop the particles while preserving their mineralogical properties for subsequent analysis. This target technology may also be useful in terrestrial studies of debris from explosions.

The collection concept is simple: a foam or other underdense medium is used to remove the kinetic energy gently from an impinging particle. A well-designed collector decelerates and stops a particle without imposing stresses beyond the critical stresses that damage the particle thermally or mechanically.

In experiments, open- and closed-cell polymer foams ranging in density from 9 to 528 mg/cm^3 were used to stop projectiles. Some targets had uniform densities; others had combinations of densities. Fibrous materials with densities from 36 to 430 mg/cm^3 and multiple layers of thin organic films were also tested as targets.

The projectiles mostly were polished aluminum spheres 1.5 to 3.2 mm in diameter, fired from two-stage light-gas guns at speeds of 1 to 7.9 km/s. Projectiles made of various combinations of natural and synthetic materials resembling dusts found in outer space were also tested. A few experiments were also conducted with 100-μm glass spheres traveling at speeds of 8 to

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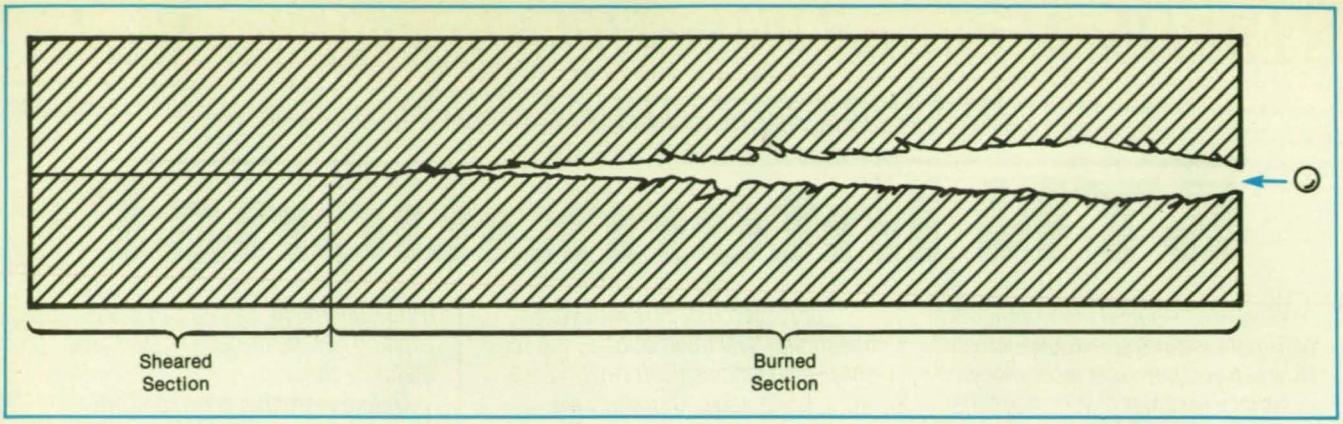


The **Hole Made by a Projectile** widens, then narrows along the direction of travel. The burned section is marked with black residues from pyrolysis or melting.

12 km/s.

Of the materials tested, polymer foams proved best for stopping projectiles intact (or with minimal loss of projectile material) at speeds around 6 km/s. Fibrous materials tend to break up the projectiles.

A typical track made by a stopped projectile is shaped like a carrot (see figure). The diameter of the entry hole is typically one to three times that of the projectile. The hole widens inward for a short distance to a maximum diameter roughly proportional to the speed at impact. For a given speed, the maximum diameter increases and the stopping distance decreases with the density of the foam.

The ratio of captured projectile mass to original projectile mass decreases with increasing speed. For 3.2-mm aluminum projectiles impinging on polystyrene foam of 16-mg/cm^3 density, this ratio is 0.83 at 6.3 km/s; for 2.0-mm projectiles impinging at 7.9 km/s, the ratio is 0.60.

This work was done by Peter Tsou of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 112 on the TSP Request Card.* *NPO-16858*

Fast Detection of Breaks in Ducts

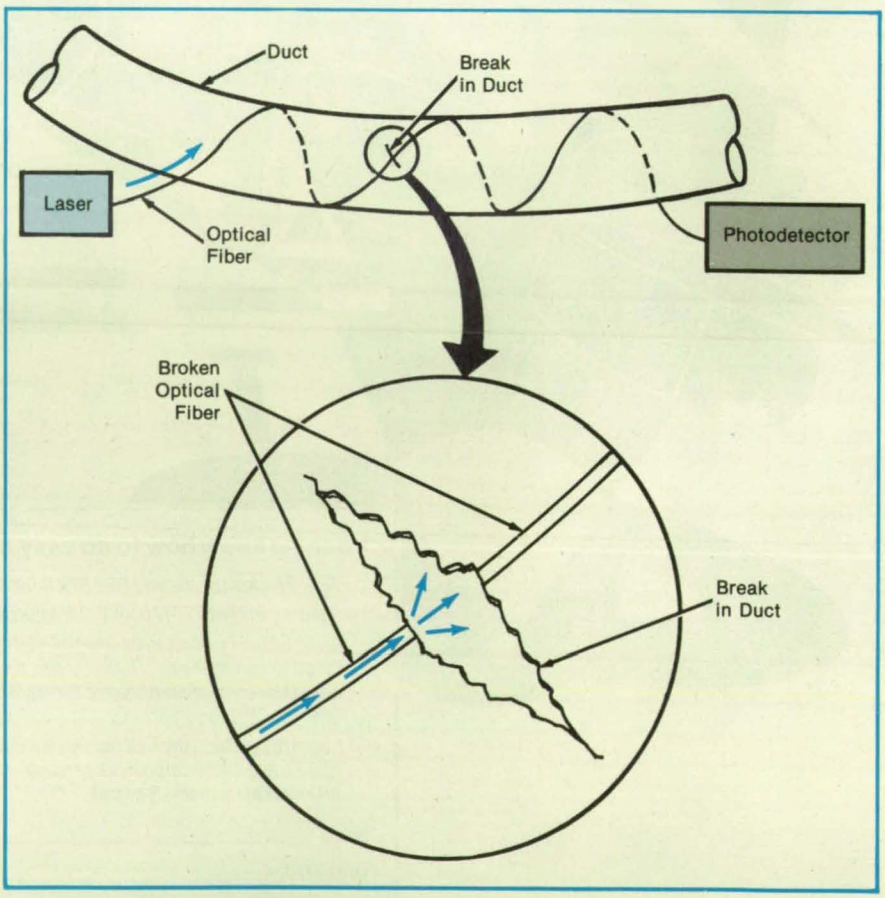
Breaks in optical fibers reveal failures in duct walls.

Marshall Space Flight Center, Alabama

A group of optical fibers would give almost instantaneous indication of imminent engine failure by monitoring the integrity of high-pressure lines and ducts, a concept suggests. The fibers would be wrapped helically around a duct or pipe and bonded to it (see figure). A crack in the wall would produce a crack in one or more fibers, interrupting the transmission of light. The interruption could be used to command a shutdown of the engine or other system to minimize damage.

Because a typical receiving photodetector at the end of a fiber can respond to changes in the light level in less than a microsecond, shutdown would be triggered faster than it is in the current method of detecting line failure that compares engine-sensor readings with "red-line" limits. Moreover, the location of the fault can be determined by measuring the travel time of light pulses reflected from the fiber break by use of time-domain reflectometry. The function of the optical fibers would not be adversely affected by electromagnetic interference.

To guard against false alarms, a voting scheme could be used to trigger a shutdown. If, for example, four out of five fibers fail suddenly, an engine shutdown could be commanded. Alternatively, the voting scheme could be applied to the time-domain-reflectometry technique to confirm the location of the failure: if three out of five fibers fail within one-fourth in. (6 mm) or another specified distance, the engine could be shut down.



A **Group of Optical Fibers Wrapped** around a duct (only one of the many fibers is shown here) carries light beams from lasers to photodiodes. A break in the duct would break the fiber bonded to it, interrupting the path of the light between the laser and the photodetector.

This work was done by Matthew A. Smith and Ray C. Delcher of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29274

Dowel Remover

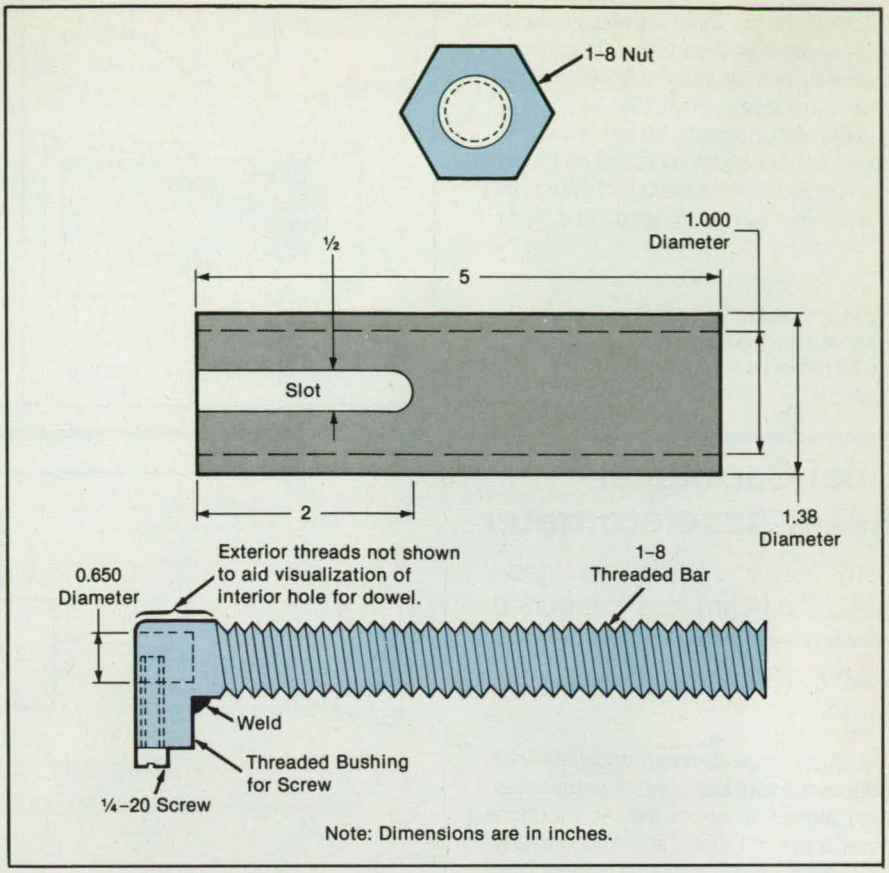
A tool extracts dowels quickly and safely.

Marshall Space Flight Center, Alabama

A special tool pulls dowel pins straight out of blind holes. The tool removes the dowels without damaging them or possibly injuring the user, unlike tools like vise grips, pliers, channel locks, hammers, and chisels. It accepts the most common dowel sizes — ⅛- to ⅝-in. (3.2- to 15.9-mm) diameter.

The tool, which is simple and inexpensive, is made from a screw, a threaded bar, a slotted pipe, and a nut (see figure). A hole at one end of the threaded bar is positioned over the protruding end of the dowel, and a screw in the bar is tightened against the dowel. The slotted pipe is slipped over the bar with the slot engaging the threaded bushing that holds the screw. The nut is installed on the threaded bar and rotated so that it presses against the slotted pipe. Continued tightening of the nut pulls the threaded bar and, with it, the dowel.

This work was done by Jerry Blisse of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29328



Simple Parts Are Combined to pull a dowel out of its hole. The tool grips the dowel firmly. Even if the tool suddenly loses its grip on the dowel, it is unlikely to injure the user.

Quick-Disconnect Valves for Modular Fluid Systems

Maintenance would be facilitated and loss of fluid minimized.

Marshall Space Flight Center, Alabama

Maintainable (that is, inspectable and repairable) valves are being developed for use as interfaces between modules or other separable components in maintainable fluid systems. Although the new valves are being designed for temperature-regulating equipment aboard a space station, they could also be used with or without modifications in a variety of liquid and low-pressure-gas systems on Earth.

The valves (see Figure 1) are based on a cartridge-in-sleeve concept. The design minimizes the loss of liquid and the ingestion of gas or other contaminants during connection and disconnection or other maintenance activities. All of the seals and moving parts within the valves are maintainable.

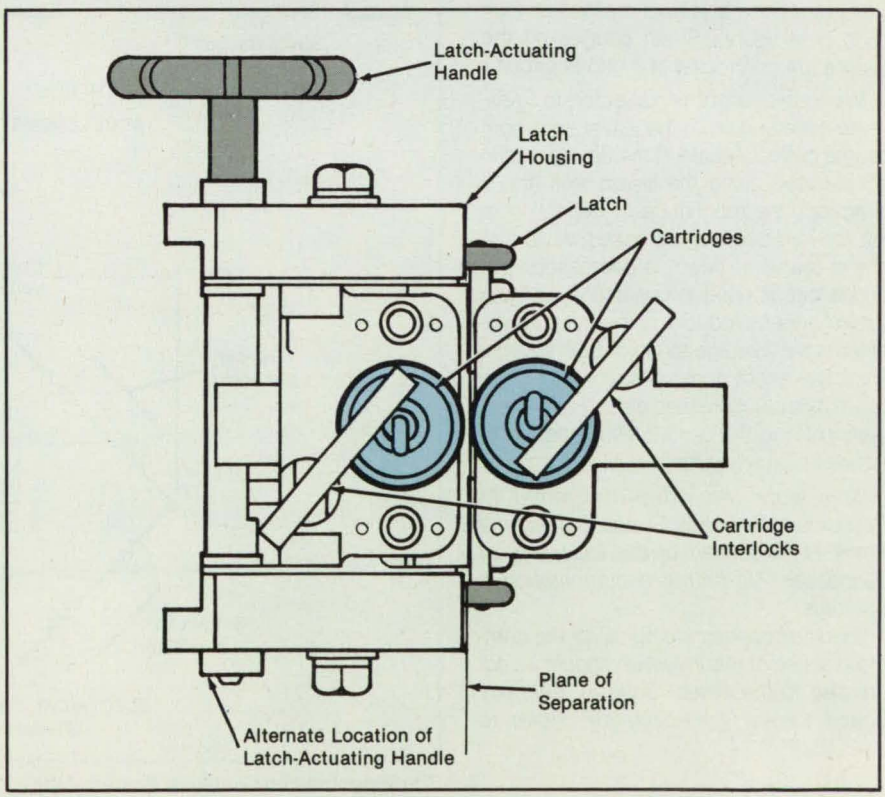


Figure 1. A **Pair of Valves** joins two plumbing subsystems, enabling them to be connected to or disconnected from each other and enabling either or both to be isolated upon disconnection.

Such features as two- or three-way switching, proportional valves, check or relief valves (see Figure 2), and some instruments can be integrated directly into valve cartridges. With the addition of probes, components larger than cartridges can be accommodated as though they fitted within the housings of the valves. In systems with damaged fluid lines, bypass lines instead of probes can be inserted into the housings.

This work was done by Charles Fluger, Rudolf Rexer, George J. Roebelen, and John B. Green, Jr., of United Technologies Corp. for **Marshall Space Flight Center**. *For further information, Circle 5 on the TSP Request Card.*
MFS-28262

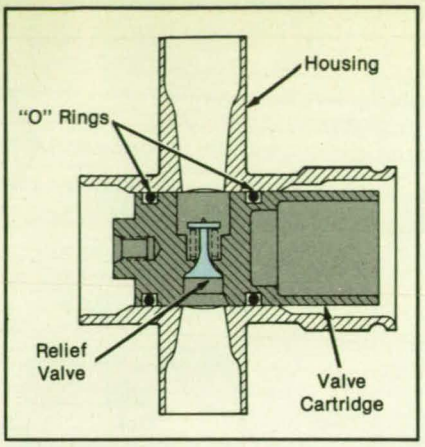


Figure 2. A **Relief Valve** is built into the cartridge of a maintainable valve; the cartridge can be removed for replacement or inspection.

Dual-Cantilever-Beam Accelerometer

Sensitivity to velocity changes along the beam axis is reduced.

John F. Kennedy Space Center, Florida

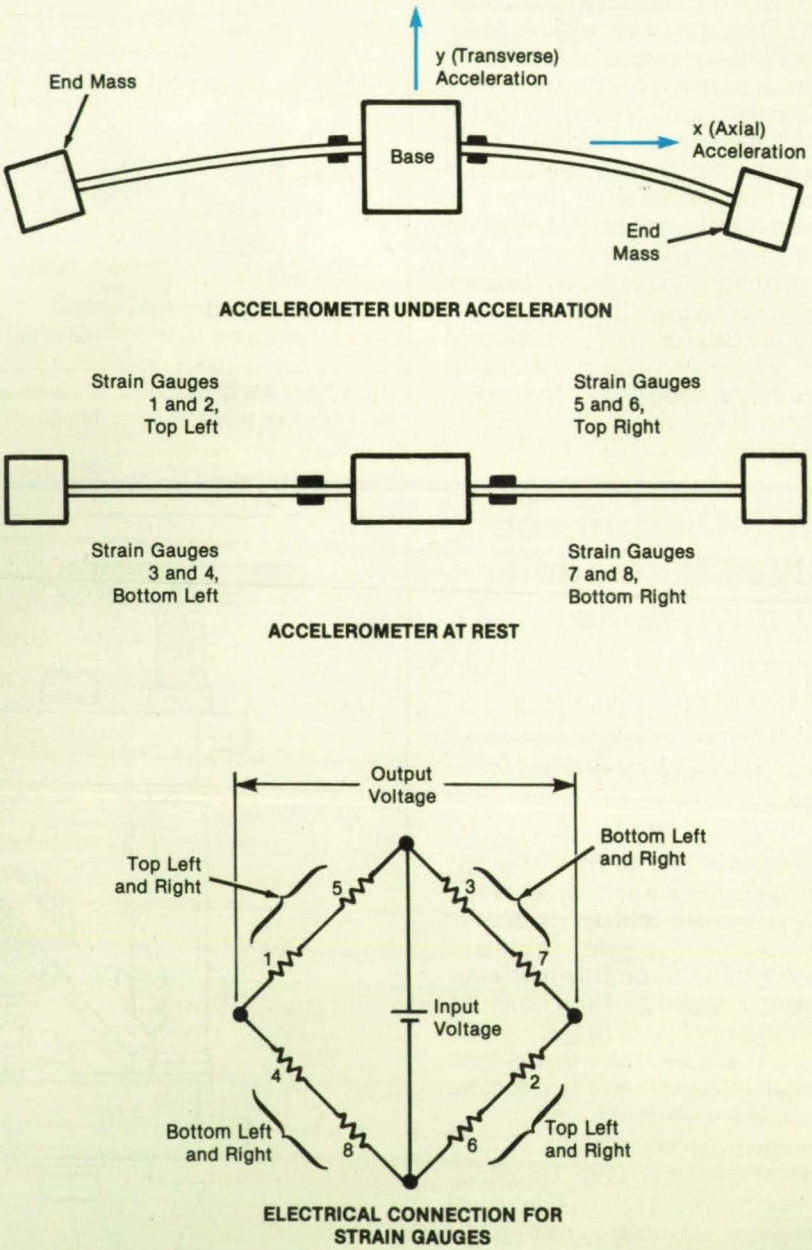
A dual-cantilever-beam accelerometer reduces the spurious signal due to acceleration along the beam axis. It therefore gives more-accurate and more-nearly-linear readings of transverse acceleration. Like ordinary single-cantilever-beam accelerometers, the new device is simple and inexpensive.

The beams are mounted on opposite sides of a base and hold masses at their ends (see figure). Strain gauges on the beams are connected in a bridge circuit.

When the sensor is subjected to transverse acceleration (in the y direction), both beams deflect equally. If the device is also accelerated along the beam axis (the x direction), the magnitude of deflection of the forward beam is increased, while that of the rearward beam is decreased. The bridge circuit used in conjuction with the strain gauges produces an output that represents the average strain of both beams. Thus, the effect of acceleration along the beam axis is suppressed electrically, effectively making the device less sensitive to acceleration along the x axis.

This work was done by Emmitt A. Reynolds of **Kennedy Space Center** *and Frank H. Speckhart of the University of Tennessee. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 20]. Refer to KSC-11235.



The **Weighted-End Cantilever Beams** of the accelerometer are deflected equally by acceleration in the y direction. When there is acceleration to the right as well as up or down, the right beam is deflected more, while the left beam is deflected less. The bridge circuit averages the outputs of the strain gauges that measure the deflections, so that the cross-axis sensitivity of the accelerometer is reduced.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Tribology — A Survey of the Science

A collection of papers covers theory, practice, history, and research.

A compendium presents six papers on tribology the study of adhesion, friction, wear, and lubrication of solid materials in contact. The first paper, "Tribology," surveys the science. It discusses adhesion and friction, noting that adsorbed surface films and oxides on metals markedly influence tribological behavior. Environmental factors thus figure strongly in the design of bearings, gears, and seals.

The paper describes the nature of adhesive, abrasive, and corrosive wear. In regard to lubrication, the paper notes that subtle differences in the molecular structure of hydrocarbons can influence adhesion and friction. In lubrication by liquids, distinct regimes can be identified. Both the physical properties of the lubricant and the operating variables affect the performance of the lubricant. With solids as high-temperature lubricants, both thermal and oxidative stability are important, as is the range of operating temperatures. Such techniques as ion plating and sputtering are being increasingly used to apply solid film lubricants.

"Boundary Lubrication — Revisited" reviews the various lubrication regimes, with particular emphasis on boundary lubrication. It illustrates the types of wear debris and the extent of surface damage for each regime. It discusses the role of boundary-surface films, their modes of formation, and important physical properties. Finally, it considers the effects of operating parameters on friction and wear in the boundary-lubrication regime.

"Solid Lubricant Materials for High Temperatures — A Review" discusses lubricants that can be used at temperatures above 300 °C in air. It discusses coatings and self-lubricating composite bearing materials, including dichalcogenides, graphite, graphite fluoride, polyimides, soft oxides, oxidatively stable fluorides, and hard coating materials. The paper evaluates the materials in terms of their temperature limits, chemical stabilities, lubricating properties, and methods of application.

"Design and Lubrication of High-Speed Rolling-Element Bearings" examines parameters that can be used to design, specify, and choose lubricants for such high-speed bearings as those in turbomachinery. The paper notes that the life expectancy and reliability now equal or exceed those of lower speed bearings. However, high-speed bearings are not components that can simply be ordered from a manufacturer's catalog. Values of design parameters must be optimized with the aid of computer programs. The management of heat and the selection of bearing materials and lubricants must be integrated into the bearing design.

"Lubrication and Cooling for High-Speed Gears" discusses the problems and failures that occur in high-speed gears. It examines the losses associated with tooth-mesh friction, bearing friction, churning, and windage and shows how the losses can be reduced and efficiency thereby improved. The paper presents several methods of oil-jet lubrication, including into-mesh, out-of-mesh, and radial-jet lubrication. It evaluates the strengths and weaknesses of each method and gives experimental and analytical data. It points up the need for improved methods for the cooling of gears at high speeds and loads.

"A Historical Perspective of Traction Drives and Related Technology" traces the evolution of traction-drive technology from early development to contemporary research. Much recent research has

centered on improving power and capacity without sacrificing simplicity. Principal research efforts include modeling the tractive behavior of lubricants; predicting the useful torque that can be passed between rollers without excessive damage to the contact surfaces; improving the durability of traction-drive materials, chiefly bearing-grade steels; developing lubricants that produce higher traction forces; and developing drive arrangements that maximize the durability, torque, and drive ratio.

This work was done by Donald H. Buckley, William R. Jones, Jr., Harold E. Sliney, Erwin V. Zaretsky, Dennis P. Townsend, and Stuart H. Loewenthal of **Lewis Research Center**. *To obtain a copy of the compendium, "Tribology: The Story of Lubrication and Wear," Circle 53 on the TSP Request Card.*
LEW-14550

Service Lives of Restored Bearings

Rebuilt units should last almost as long as new ones.

A report describes theoretical and experimental studies of the lifetimes of restored ball and cylindrical-roller bearings. The results of this and related studies have obvious implications for economy and safety in modern high-speed machinery, especially in the aircraft industry, where the inspection and rejection or replacing of bearings are now standard practice.

A used bearing is first inspected visually. If the raceways are damaged superficially (to a depth of less than 0.05 mm) and if they remain hard enough, the bearing is considered a candidate for restoration. Where necessary, the faces, bores, and outer diameters are ground and plated with either nickel or chromium to allow regrinding to the original outer dimensions. The raceways are then ground to a depth between 0.05 and 0.15 mm to remove all superficial damage and a portion of the subsurface fatigue damage.

The bearing is then fitted with new rolling elements of diameter equal to the original diameter plus twice the depth of regrinding. After inspection of the bearing separator for cracks, the bearing is reassembled. Although the raceways and rolling elements are slightly oversize, for engineering purposes the stress levels and geometrical relationships among the components are essentially identical to those of the original bearing.

The fatigue life of a rolling-element bearing is calculated by the Lundberg-Palmgren formula, which gives the relationships among the probability of survival, the number of stress cycles to failure, the stress, the stressed volume, and the depth of occurrence of the maximum orthogonal reversing shear stress. For new elements, the statistical dispersion in lifetimes is described by the Weibull distribution.

This theory of failures is applied to compare the lives of restored bearings to the lives of new ones. In a restored bearing, the location of the maximum orthogonal reversing shear stress is shifted deeper into the original material by the depth of regrinding. Thus, the stressed volume of a restored bearing includes a newly stressed portion plus an older portion that has a longer history of stress cycles. The probability of survival of the restored bearing is therefore estimated as the product of the probability of survival of the used material with that of the new material. A correction is made to account for the defective bearings discarded after inspection.

The final result of this theory is an equation for the probability that the restored bearing will survive an additional specified number of stress cycles as a function of the fraction of the stressed volume ground away during restoration and the number of stress cycles since manufacture at which it was restored. When representative parameters are inserted in this equation, it predicts that the lifetime during which there is a 10-percent probability that a restored bearing will fail ("10-percent life") ranges from 74 to 100 percent of the 10-percent life of a new bearing.

In the experiments, 250 bearings of three different types were restored. Of these, 30 of each type were chosen at random and tested under realistic operating conditions for 1,600 hours. None of the bearings suffered a failure related to regrinding. Two failures were due to defective rolling elements and were typical of those that occur in new bearings.

This work was done by Erwin V. Zaretsky of **Lewis Research Center**. *Further information may be found in NASA TM-88871 [N87-18820], "Effects of Surface Removal on Rolling-Element Fatigue."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14704

★ ★ **Technology Forecast** ★ ★

Sensors

"Smart sensors that combine data processing and sensing functions in a integrated circuit chip will continue to be a hot research area in 1989. These devices are presently limited in use because their integrated circuitry can only withstand temperatures of a few hundred degrees Celcius. NASA Lewis is developing new composite materials that will allow smart sensors to be used in high-temperature applications such as structural testing for the National Aerospace Plane.

We are also investigating the potential use of lasers for remote sensing. One technique we're developing is laser speckle correlation, in which the interaction of a laser beam with the test surface results in the formation of a speckle pattern. The pattern and the features of the test surface closely match, allowing one to track material changes by following changes in the speckle pattern. This technique could be used in development of ceramic materials for jet engine components. There's currently no contact-type sensor that can survive the 1650°C under which these materials are tested. A laser-based system could remotely sense strain, temperature and heat flux in the proposed material."

Dr. W. Dan Williams,
Chief of the Research Sensor Technology Branch at NASA's Lewis Research Center

★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Tribological Properties of Coal Slurries

A flocking agent (coal oil) in a coal/methanol slurry reduces wear.

A report describes a study of the tribological properties of coal/methanol slurries with a pin-on-disk tribometer. Coefficients of friction, rates of wear of the steel pin, and morphological studies of the worn surfaces were conducted on pins and disks of AISI 440C HT (high-temperature) stainless steel and M-50 tool steel, both of which are used as bearing steels. Coal slurries have been considered as replacement fuels in terrestrial oil-burning facilities and as possible fuels for future aircraft turbine engines. The rates of wear of metallic components through which the slurries flow could limit such practical applications.

In a series of runs, a pin and a disk of each steel were slid against each other dry, in methanol, in a slurry of fine coal particles in methanol, and in a similar slurry to which a coal-oil flocking agent was added. The hemispherical tips of the pins, each 0.467 cm in radius, were pressed with a force of 9.8 N against the 6.3-cm-diameter disks, which were rotated at 100 rpm to obtain a linear sliding speed of 0.26 m/s.

The coefficients of friction measured with methanol alone and with the two slurries containing methanol were nearly the same; all were in the range of 0.16 to 0.19. With 440C HT steel, the rates of wear for the coal/methanol slurries without and with the flocking additive were 23×10^{-15} and

15×10^{-15} m^3 per meter of sliding, respectively. The corresponding rates with M-50 steel were slightly higher. When the methanol was allowed to evaporate from the slurry with the flocking additive, the coefficient of friction dropped to 0.10 and the rate of wear dropped to 4×10^{-15} m^3 per meter of sliding. The coal slurry (with and without the flocking additive) induced cracking and spalling on the worn surface of the M-50 but not on that of the 440C HT steel, indicating that the type of steel selected for use with slurries could be very important.

This work was done by Robert L. Fusaro of **Lewis Research Center** *and Dale L. Schrubens of Texas A&I University. Further information may be found in NASA TM-89930 [N87-24565], "Tribological Properties of Coal Slurries."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. The report is also available on microfiche at no charge. To obtain a microfiche copy, Circle 85 on the TSP Request Card.
LEW-14739

Trajectories for Space Ambulance

Energy and time requirements for moving the sick or injured in outer space are analyzed.

A report presents a concept for a space ambulance that can move as quickly and economically as possible between orbits. The report describes a variety of rendezvous maneuvers between space stations in geocentric orbits at altitudes ranging from 200 km to the geosynchronous altitude. It analyzes minimum times to complete rendezvous with an orbiting medical station.

Usually, the ambulance would fire its engines twice on a mission — one accelerating impulse when it leaves a space station with a sick or injured crewmember and one decelerating impulse before it docks at the medical station. The report focuses on the conservation of propulsive energy but nevertheless considers conditions under which large expenditures of propulsive energy would be required for coplanar-orbit transfers or for orbital-plane changes. Throttleable engines are suggested for the gentle transfer of crewmembers suffering from spinal or head injuries, so as not to exacerbate their conditions.

A space station should be equipped to generate all viable rendezvous options continuously so that the best route can be selected instantly when an emergency occurs, the report notes. As the altitudes of the space station and the medical station increase, so does the time available for accomplishing rendezvous maneuvers in less than one orbital period of the medical station. However, the propulsion for rendezvous becomes greater as the altitudes increase.

If the ambulance misses an opportunity for a rendezvous with the medical station, it can use subsequent opportunities efficiently by moving to an apogee beyond the altitude of the medical station. Then the time to complete the rendezvous will be an integral multiple of the orbital period of the medical station.

The amount of propulsion required will reach a maximum when the ambulance uses two medical-station orbital periods to rendezvous. However, the amount of propulsion required is quite small when the time for a rendezvous approaches one orbital period of the medical station or when the time is many integral multiples of this period.

This work was done by Walter C. Nelson of Research Corp. for Shiro Furakawa of McDonnell Douglas Astronautics Co. for **Kennedy Space Center**. *To obtain a copy of the report, "Orbit Design for a Space Ambulance Vehicle," Circle 124 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 20]. Refer to KSC-11296.

Machinery

Hardware Techniques, and Processes

General-Aviation Control Loader

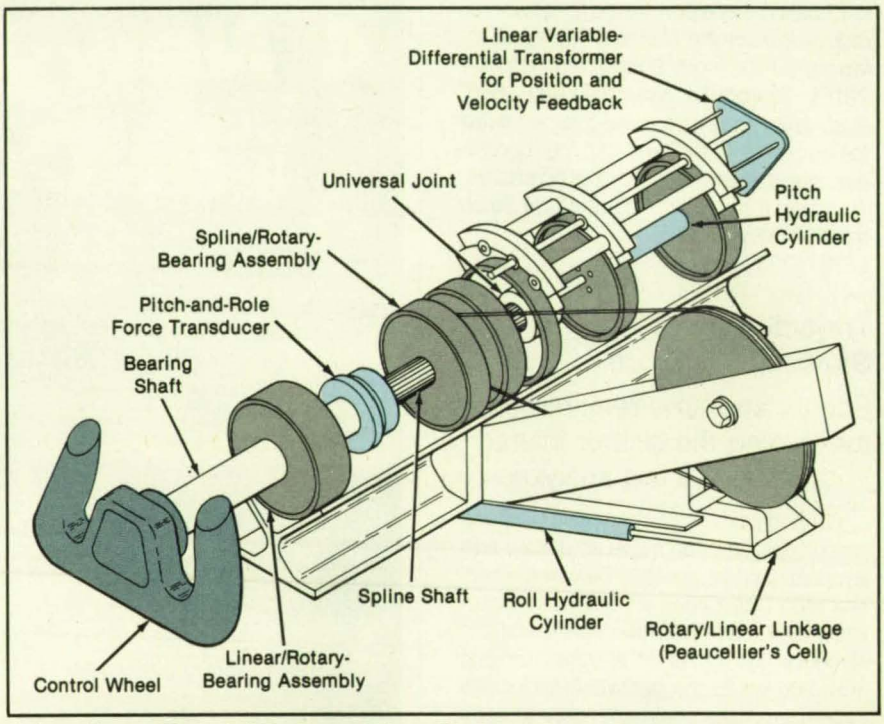
An artificial-feel system is designed for general-aviation flight simulators.

Langley Research Center, Hampton, Virginia

A variable-characteristic artificial-feel system, or control-loading system, is compatible with the requirements of real-time flight-simulation research for the general-aviation-class airframe. Control-loading systems have long been used to provide realistic control-force feedback in the simulation of flight for both training and research. However, these systems have been directed at fighter and transport applications. The new system was developed to replace directly the lateral and longitudinal (wheel and column) controls in a general-aviation cockpit for use in flight-simulation research.

The system (see figure) employs two small-bore hydraulic cylinders controlled by precise electromechanical servo-flow-control valves. It uses a Peaucellier's cell to convert the linear motion of the roll hydraulic cylinder to rotary motion. An analog operational-amplifier network serves as an interface with a digital computer via analog-to-digital signal-conversion equipment.

The system provides computer-controlled force feel as the control wheel is moved by the pilot in the longitudinal (pitch) and lateral (roll) axes. Potentiometers are used to set required values of such quantities as gradients, damping, and cable stretching. Analog multipliers enable the computer to vary gradients and damping proportionally from 0 to 100 percent of maximum simulated values.



Using a Peaucellier's Cell To Convert Linear Motion to Rotary Motion, this control-loading system provides realistic control-force feedback to the cockpit wheel and column controls.

The development of the system is complete, and the unit is operational. The system is installed in NASA Langley Research Center's General-Aviation Cockpit Simulator, where it serves as the primary flight-control system.

This work was done by Daniel W. Baltrus, Leroy F. Albang, John A. Hallinger, and W. Wayne Burge of Sperry Corp. for **Langley Research Center**. *For further information, Circle 164 on the TSP Request Card.*

LAR-13707

Portable Liquid-Injecting System

A lightweight gun provides controlled, adjustable volumes of liquid.

Lyndon B. Johnson Space Center, Houston, Texas

A portable injecting-gun system dispenses a predetermined amount of liquid at moderately high pressure. Although most dispensing and metering systems are large and heavy, the new system can be carried on a tool belt (see figure).

The system includes an injecting nozzle, a pump driven by an air cylinder, a four-way valve to control the air, an electronic timer, a reservoir of liquid, pneumatic regulators, and a trigger assembly. The operator inserts the nozzle into a hole in the workpiece. Pressing the trigger directs air to the aft end of the pump. The air activates the timer and drives the pump plunger, dispensing the liquid through the nozzle into the hole and simultaneously providing a small purging flow of air to aid the entry of the liquid.

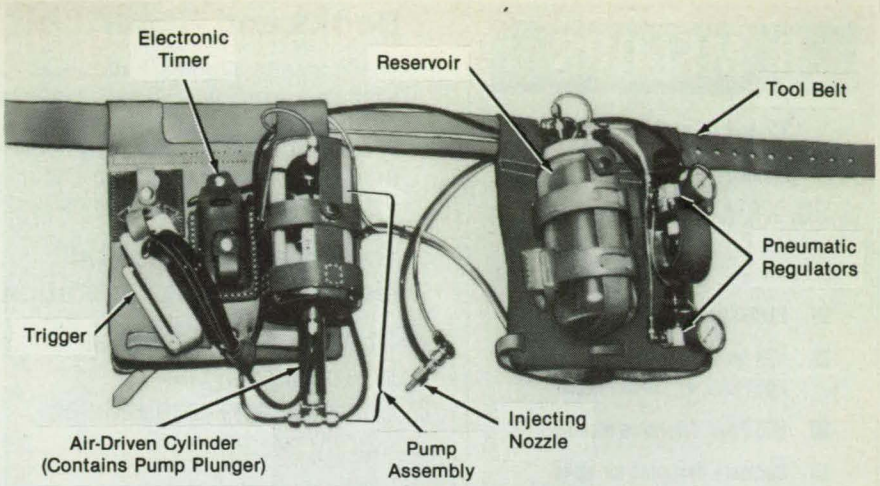
A buzzer in the timer sounds 4 seconds after the trigger has been pressed, signal-

ing the operator that the proper amount of liquid has been dispensed. Releasing the trigger directs air to the forward end of the pump, pushing back the plunger and stopping the flow of liquid and purge air through the nozzle.

The volume of injected liquid can be varied from 1 to 4 cm^3. A threaded collar on the air cylinder of the pump lets the operator make the adjustment easily.

Two check valves — one on the intake side of the pump and one on the outlet end — control the direction of liquid flow. A third check valve at the injecting nozzle minimizes the spillage of liquid and prevents the purge air from entering the liquid line. When liquid is being injected, pressure closes the intake check valve and opens the outlet check valves at the pump and the injecting nozzle. When the pump plunger retracts, it creates a suction that closes the outlet check valves and opens the inlet check valve so that liquid can refill the pump chamber.

When the 1-liter liquid reservoir is depleted, the operator can quickly replace the empty bottle with a full one. The bottles are equipped with quick-disconnect fittings, to prevent spillage when they are changed, and with relief valves, to protect them in case they are overfilled or overpressurized.



A Tool Belt Holds Components of the liquid-injecting system. The pump and four-way valve are combined in a nylon housing. They are connected to the injecting nozzle and the other components by polyvinyl tubing.

This work was done by T. Shuck, F. Chin, and M. Hansen of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 8 on the TSP Request Card.* *MSC-21308*

Seal for Precooling a Turbopump

A diaphragm reduces misalignment.

Marshall Space Flight Center, Alabama

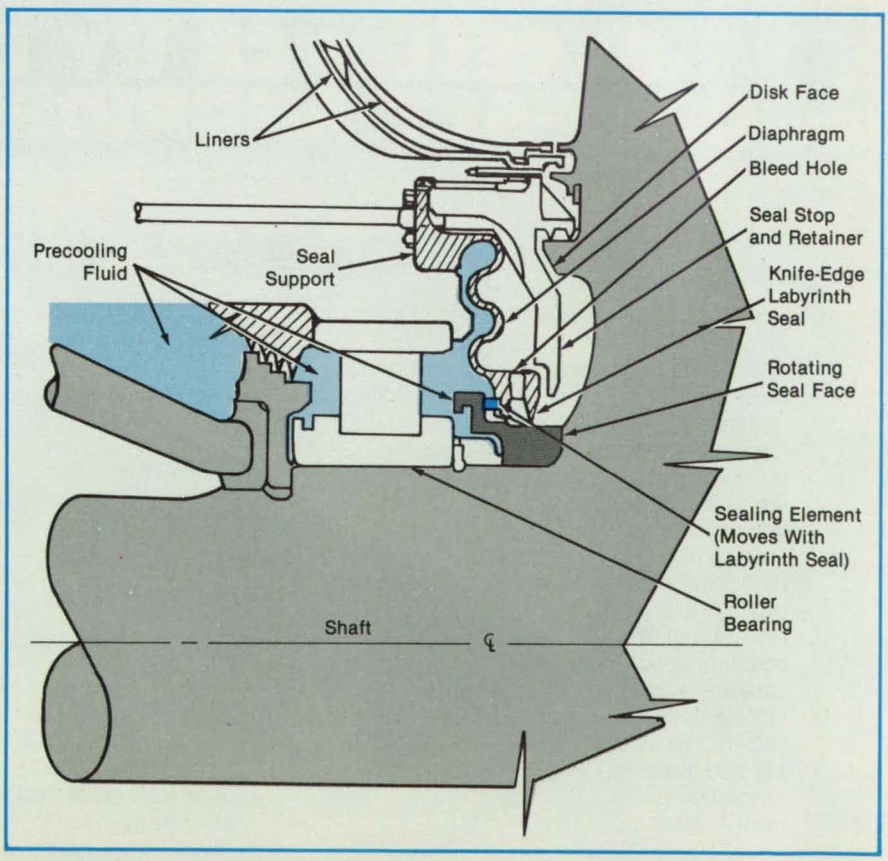
A rotary seal retains precooling fluid in the pump section of a cryogenic turbopump, preventing the fluid from entering the turbine section. The precooling fluid is needed to lower the temperatures of the pump parts, to reduce thermal shock and boiling when the cryogenic liquid enters the pump.

Before the turbopump is started, a sealing element rests against a highly-polished rotating seal face (see figure). When the turbopump is first assembled, the diaphragm holding the sealing element is bent to give the necessary sealing force against the seal face.

When the turbopump is started, the internal pressure of the liquid in the pump deflects the diaphragm axially until it seats on a seal stop. The portion of the fluid that leaks past the sealing element splits, part of it going through a bleed hole to cool the outer turbine elements and part of it leaking past a labyrinth seal to cool the liners and the rear face of the turbine disk.

This work was done by Samuel S. Owen and R. C. Mulready of United Technologies Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-28270.



Precooling Fluid is held in the pump section of a turbopump by a knife-edge labyrinth seal on a diaphragm.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Detecting Wear in Ball Bearings During Operation

Strain-gauge signals at harmonics of ball-bearing-cage frequencies signify wear.

A brief report describes experiments in a continuing effort to interpret vibrations of machinery in terms of wear in ball bearings. A proportionality can be established experimentally between the amount of wear and the amplitudes of harmonics of the rotational frequency of the bearing cage found in vibration signals picked up by nearby strain gauges. The functional relation that applies in a given situation is determined by collecting the strain-gauge data for several bearings during use and correlating these data with ball-wear measurements made on the same bearings after use. The same method should be applicable to roller bearings.

The method is being used to monitor wear on bearings in high-pressure oxygen turbopumps used in the Space Shuttle main engine. Data have been collected from the bearings in a series of pumps. Correlation coefficients have been calculated separately for minimum, average, and maximum ball-wear data for the first three harmonics. Of the nine correlation coefficients, three had less than a 1-percent probability of occurring by chance, five a probability between 1 and 5 percent, and one a probability greater than 5 percent.

These results are based on signals from a strain gauge located inside the pump. The same cage-frequency harmonics have also been observed in signals from externally-mounted strain gauges and accelerometers. When sufficient data from such external sensors will have been collected, a correlation analysis of those data will also be run.

If all balls are worn to the same diameter, there are no vibrations at the cage frequency or its harmonics. Thus, the method can be used to detect only the degree of unevenness in the wear on the various balls.

This work was done by Michael J. Hine of Rockwell International Corp. for **Marshall Space Flight Center**. *To obtain a copy of the report, "In-Test Measurement of Bearing Ball Wear," Circle 99 on the TSP Request Card.* *MFS-29376*

★ ★ ★ ★ ★ **Technology Forecast** ★ ★ ★ ★ ★

Dynamic Power

"Solar dynamic systems will provide a more efficient method of power generation for future space ventures such as the Space Station, which will employ a closed Brayton cycle system. Dynamic systems presently offer a specific power of four watts per kilogram of weight, as opposed to only about two and one-half watts from conventional photovoltaic units. In addition, the smaller overall size of these fluid systems will result in reduced friction drag.

NASA Lewis is working with the Departments of Defense and Energy to create advanced solar concentrators, heat receivers, and radiators that will greatly improve the power to weight ratios of dynamic systems. We project efficiencies of 15 watts per kilogram and above, which translates into multibillion dollar savings over the course of the Space Station's lifetime. Lewis engineers also are developing a free-piston Stirling engine which one day may serve as a lightweight, high-performance power source for spacecraft. And for terrestrial applications, Lewis and the Department of Energy are building kinematic Stirling engines for eventual use in buses, trucks, and other large vehicles. The advantages this external combustion engine holds over standard automotive power plants include better gas mileage, longer service life, and the ability to run on a variety of fuels."

Dr. Marvin Warshay,
Chief of the Solar Dynamics and Thermal Systems Branch at NASA's Lewis Research Center

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Fabrication Technology

Hardware Techniques, and Processes

Programmable Grit-Blasting System

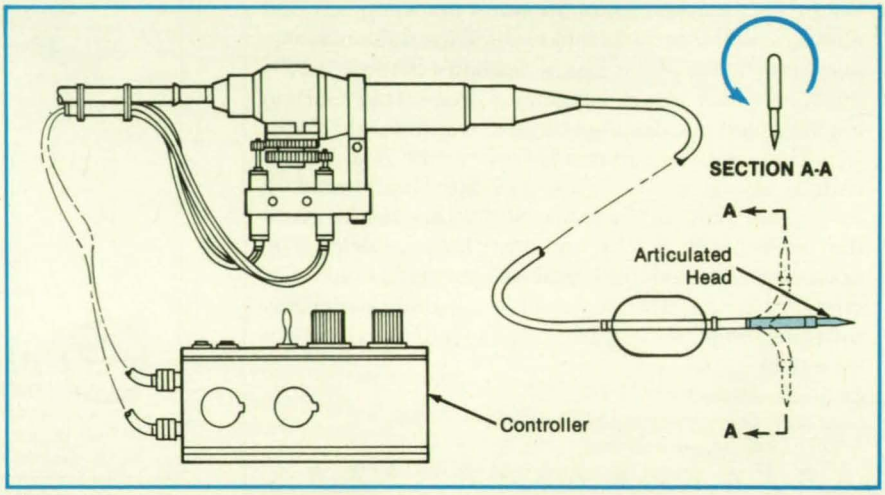
A servocontroller would establish the trajectory and orientation of the head.

Marshall Space Flight Center, Alabama

In a programmable grit-blasting system undergoing design, a controller would move the blasting head to precise positions to shape or to remove welding defects from parts. The controller would hold the head in position for a preset dwell time and move the head to a new position along a predetermined path.

The system could be used to remove welding defects in blind holes. It would also be well suited for repetitive production operations in a grit-blast box; for example, the iterative shaping of turbine blades or removal of recast layers from electrical-discharge-machined parts.

The blasting head could be rotated by servomotors through an arc of 120° around either of two perpendicular axes (see figure). The controller could store programs for as many as 31 different trajectories, including large numbers of discrete x and y coordinates and dwell times.



The **Position of the Articulated Head** is established by a pair of servomotors according to programmed signals from the controller. The head is similar to that of a video borescope.

This work was done by Richard K. Burley of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 165 on the TSP Request Card.*
MFS-29220

Holding Irregularly Shaped Parts for Machining

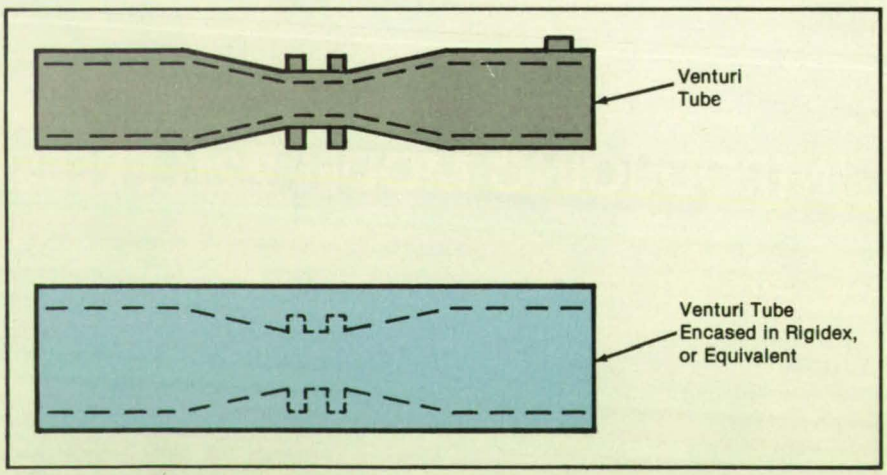
A temporary covering can be clamped.

Marshall Space Flight Center, Alabama

A part that has complicated, irregular outside contours can be clamped for precise machining of internal passages with the aid of a simple method. The exterior of the part is cast in Rigidex, or equivalent epoxy. The epoxy forms a wall that can be clamped. The interior of the part — a venturi tube, for example (see figure) — can then be machined to a finish of 125 μin. (3 μm) or finer.

With the epoxy covering, the part can be held in the chuck of an ordinary lathe and cut without excessive bending. More-costly finishing methods like honing or electrical-discharge machining are unnecessary. When machining is finished, the epoxy is melted away by heating the part to 200 °F (93 °C).

This work was done by Burt W. Hilton and Rick R. Wilson of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*



A **Venturi Tube** (top) encased in Rigidex, or equivalent, (bottom) becomes sufficiently rigid that its interior can be machined precisely. Later, the epoxy is melted away.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29344.

Monitoring Welding-Gas Quality

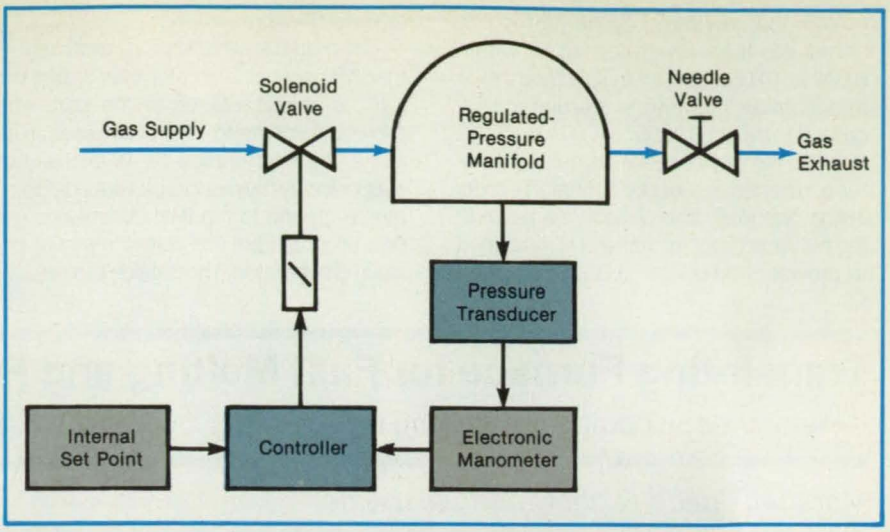
A control system prevents weld defects.

Marshall Space Flight Center, Alabama

A system monitors welding gas to ensure that its characteristics are within predetermined values. The system responds to changes that might go unnoticed by a human operator and acts quickly to prevent weld defects.

The system independently measures three gas characteristics: pressure, oxygen content, and moisture content. If any of these characteristics deviates from its alloted range or maximum level, the system activates an alarm circuit. The operator will then be unable to initiate an arc, or if welding is already in progress, the arc current will be shut down immediately.

A pressure controller associated with the system (see figure) maintains gas pressure stably and accurately. If the controller fails or if the gas-supply pressure varies beyond the controllable range, the monitor alarm takes over and terminates welding.



An **Electronic Pressure Controller** employs various amounts of gain, equalization, and compensation to respond to changes in the gas-supply pressure. The controller works in conjuction with the pressure/oxygen/moisture monitor.

This work was done by Kevin L. Huddleston of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29195

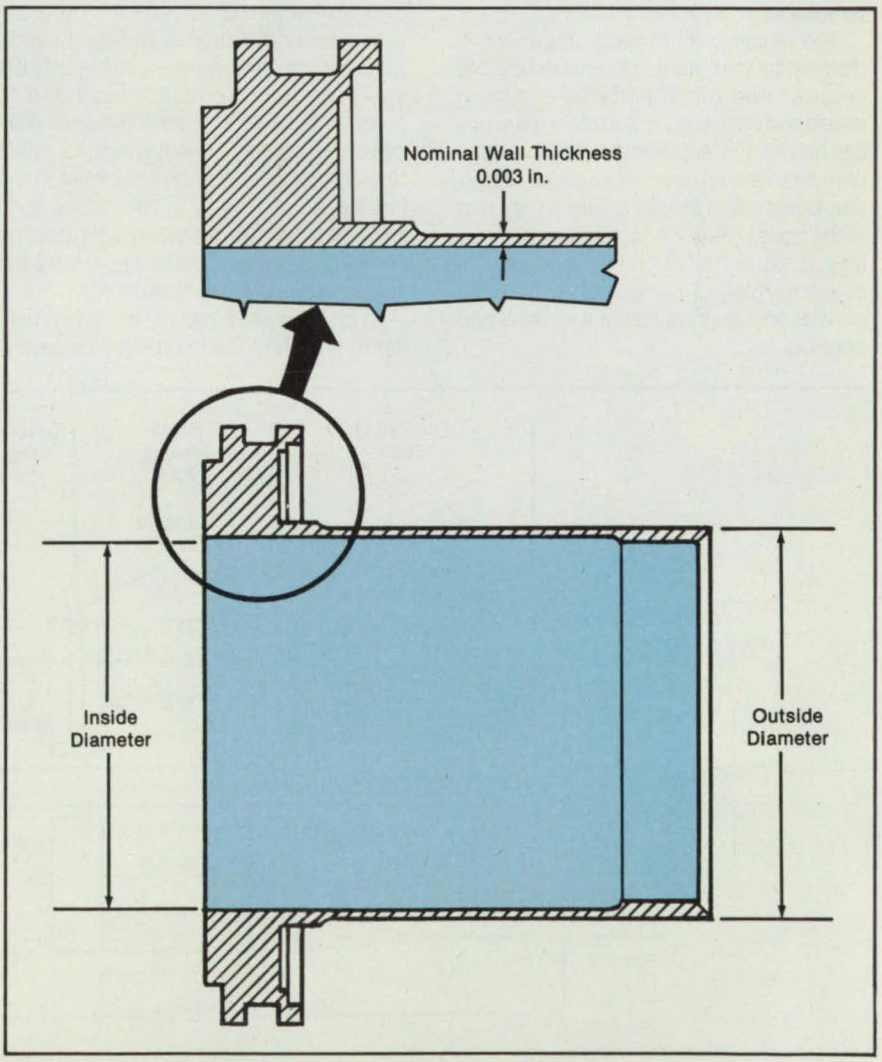
Machining Thin-Walled Cylindrical Parts

The thermal expansion and contraction of a beryllium copper mandrel is exploited.

Lyndon B. Johnson Space Center, Houston, Texas

Cylindrical walls only a few thousandths of an inch thick can be machined accurately and without tears or punctures with the aid of a beryllium copper mandrel. The mandrel is chilled so that it contracts, then is inserted in the cylinder. As it comes to room temperature, the mandrel expands and fits snugly inside the cylinder. The mandrel will not allow the part to slide and provides a solid backup to prevent deflection when the part is machined by a grinding wheel. When machining is finished, the cylinder-and-mandrel assembly is inserted in dry ice so that the mandrel contracts and can readily be removed from the part.

The method has been used to grind Inconel* 718 nickel alloy cylindrical parts with a wall thickness of 0.003 in. (0.76 mm) (see figure), with a rejection rate of less than 10 percent. Previously, more than 50 percent of the parts had to be rejected when the outside diameter was finish-ground and the inside diameter was then bored and ground; or, alternatively, a standard tapered mandrel was inserted, and the outside diameter was turned and ground.



A **Thin-Walled Cylindrical Part** is supported during outside-diameter grinding by an interference-fit mandrel. The mandrel is sized for the inside diameter plus 0.0001 in. (0.0025 mm).

With the new method, the part is first annealed, then rough-turned to within 0.002 in. (0.051 mm) of its specified inside and outside diameters, hardened, jig-ground to within 0.0005 to 0.001 in. (0.012 to 0.025 mm) of its specified inside diameter, and honed and lapped to final size on its inside diameter. The outside diameter of the beryllium copper mandrel is machined to provide a 0.0001-in. (0.0025-mm) interference fit with the part.

The mandrel, which has a coefficient of thermal expansion greater than that of the part, is chilled, placed in the part, and allowed to come to room temperature to make the interference fit. With the part supported by the mandrel, its outside diameter is ground to the final dimension. The part and mandrel are chilled again in dry ice and separated. The outside diameter of the part is then inspected with "go/no-go" rings.

*Inconel is a registered trademark of the Inco family of companies.

This work was done by Joe Cimbak, Jim Spagnolo, and Dan Kraus of United Technologies Corp. for **Johnson Space Center**. *No further documentaion is available.*
MSC-21260

Translating Furnace for Fast Melting and Freezing

Ceramic/metal composites will be made during low-gravity airplane maneuvers.

Marshall Space Flight Center, Alabama

A developmental translating-furnace apparatus will be used to make ceramic/metal composite materials during parabolic trajectories of a KC-135 airplane that simulate low gravity. Mathematical modeling has shown that the apparatus will be able both to melt the metal alloys and to solidify the resulting composite specimens during the 22- to 30-second low-gravity intervals.

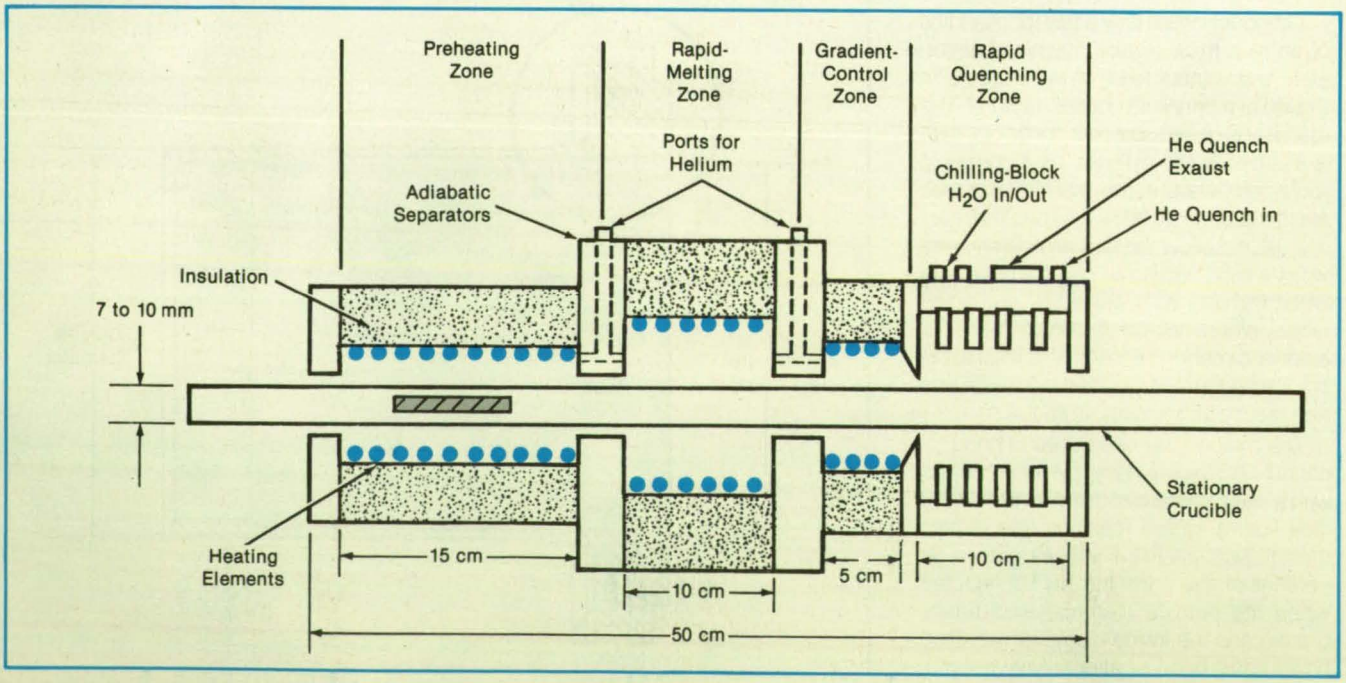
The requirement of rapid processing is dictated by the nature of the materials. The ceramic and metal particles are intermixed and dispersed uniformly in the crucible before the experiment. The ceramic particles remain solid during the experiment and have a density different from that of the metal. Thus the metal must be melted and resolidified during the brief interval of uninterrupted low gravity to prevent gravitational segregation of the metal and ceramic.

The furnace assembly (see figure) is similar to a directional-solidification furnace in both design and function. It contains three heating zones and one cooling zone. The specimens are contained in a cylindrical crucible of refractory material.

Initially, the furnace is placed so that a specimen is held in the preheating zone at a temperature just below the melting point. Shortly after the beginning of the low-gravity maneuver, the furnace is moved rapidly (about 10 cm/s) along the crucible until the specimen is in the hotter rapid-melting zone. About 5 to 10 s after the specimen becomes molten, the furnace is again moved rapidly to put the specimen in the cooling zone. The gradient-control zone between the rapid-melting and cooling zones can be used optionally to vary the quenching rate in the specimen.

In an alternative design, the rapid-melting zone is shortened to about 1 cm, and a second water-cooled zone is placed between the preheating zone and the rapid-melting zone. This configuration causes a small molten zone to be formed in the specimen between two solid zones. The furnace is translated at a controlled speed during repeated intervals of high and low gravity, causing portions of the specimen to be melted and solidified during each such interval. This mode of operation will produce results analogous to those obtained in previous experiments with pure alloys.

This work was done by F. Workman, R. J. Suggs, P. A. Curreri, E. C. Ethridge, D. T. Perkinson, S. Tucker, and G. A. Smith of **Marshall Space Flight Center**. *For further information, Circle 159 on the TSP Request Card.*
MFS-26064



The **Furnace Assembly** moves along the crucible in a programmed manner to preheat, melt, and solidify the specimen during an interval of less than 22 s.

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8818A	to 640M pts	100 MS/sec	120 MHz typ.	8 bits	1
6810	to 8M pts	5 MS/sec	2.5 MHz	12 bits	4/2/1
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Making Intricate, Thin Gaskets

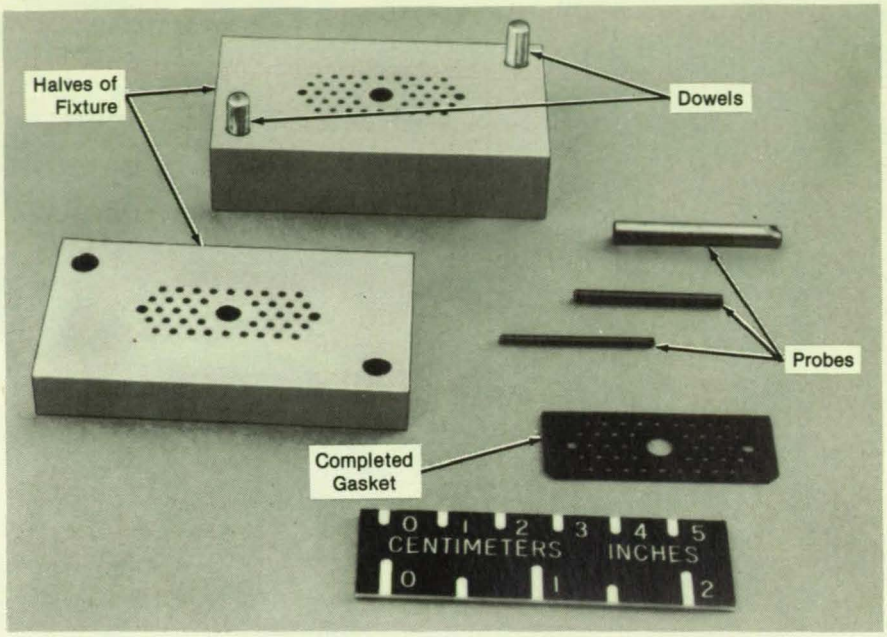
Elastomeric gaskets are fabricated precisely in a simple aluminum fixture.

Langley Research Center, Hampton, Virginia

An effective but inexpensive method has been developed for quickly fabricating intricate thin-film elastomeric seals for use in instrumentation manifolds. The manufacture of thin-film gaskets had previously required costly and time-consuming special machine setups because of the physical characteristics of the elastomeric materials used. The new method uses aluminum stock and standard machine practices to prepare intricate thin-film seals quickly.

An aluminum fixture (see figure) is made with holes in the pattern desired in the gasket. The fixture is made in two halves, top and bottom, large enough to contain at least two aligning dowel pins placed outside the gasket area. The two halves are positioned together, and the holes in the desired pattern are drilled through both halves of the fixture.

The fixture is taken apart, and the elastomeric gasket materials are placed between the two halves. Probes with 0.002 to 0.004 in. (0.05 to 0.010 mm) clearance of the diameter of each specified hole are heated to approximately 1,200 °F (about 650 °C). The hot probes are then inserted into the fixture holes through the gasket materials. The shank ends of straight shank drills work extremely well as the probes for sizes up to 0.5 in. (12.7 mm) in diameter. Probe sizes, insertion rates, and temperatures are adjusted to suit the gasket materials and configuration. After all the holes have been burned, the excess material is trimmed around the outside of the fixture. The two halves are then separated, and the completed gasket is removed.



Holes Are Burned Through the Gasket Material with hot probes, using the aluminum fixture for precise alignment.

This technique eliminates the costly and time-consuming methods previously used to fabricate intricate thin-film seals. The sizes and locations of the holes in the gasket are controlled by the fixture, and mistakes are limited. Also, replacement gaskets can be made quickly and easily. This method has already been used to make intricate thin-film seals for a variety of projects at NASA Langley Research Center.

This work was done by Wayne D. Geouge of **Langley Research Center**. *No further documentation is available.*
LAR-13681

Substrates for High-Temperature Superconductors

A new use is found for a process described previously.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed hot-dipping process would prepare materials well suited to serve as substrates for high-temperature superconductors like $YBa_2Cu_3O_{7+x}$. The process would make it possible to produce substrates that combine the properties needed for a given application — such properties as flexibility, strength, long grains, and a <001> crystal orientation. These properties favor the growth of superconductive films that can carry high current and can be fabricated in a variety of useful shapes.

The process, to be used in making solar cells, was described in "Hot-Dipped Metal Films as Epitaxial Substrates" (NPO-15904), *NASA Tech Briefs*, Vol. 8, No. 3 (Spring 1984), page 412. The substrate would be formed by dipping an inert support — a subsubstrate — into a melt of the substrate material. A thin film of the substrate material would solidify as a sheet of large crystals as the support is slowly withdrawn. The superconductor would then be deposited on the substrate as an epitaxial film by magnetron sputtering, chemical-vapor deposition, molecular-beam epitaxy, or another related process.

The substrate material would be chosen so that its crystal shape, dimensions, and orientation closely match those of $YBa_2Cu_3O_{7+x}$. Candidate substrate materials include Tl, body-centered-cubic alloys like LaTl and LaCd, and several metal halides and oxyhalides.

The superconductor film grown on such a substrate would share the same large or long crystalline shape of the substrate. It would no longer be necessary to rely on brittle, macrocrystalline blocks of ceramics like strontium titanate as substrates. Instead, the superconductor could be made as flexible wires, sheets, and other forms as required.

This work was done by Paul J. Shlichta of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 72 on the TSP Request Card.*
NPO-17317

Technology Forecast

Superconductivity

"Now that the initial hype surrounding high-temperature superconductivity has leveled off, we have a much clearer picture of the near- and long-term potential of these new materials. Industrial applications over the next few years are likely to be in the microelectronics field, specifically in creating interconnections between chips on a circuit board. As for space applications, the most immediate use for superconductors is in the development of thin-films for fabrication into superconducting quantum interference devices (SQUIDs). The new ceramics may also be suitable for magnetic suspension of lightweight, high-precision pointing systems and, eventually, rotating machinery.

Applications requiring bulk materials, such as superconducting power transmission lines and generators, are still a long way off. Bulk superconductors are presently much too brittle and have too poor a critical current density to be put to practical use. Groups funding research in this area will need to be very patient indeed if they expect to see a return on their investment."

Dr. Eugene Urban, Chief of the Cryogenics Physics Research Branch at NASA's Marshall Space Flight Center

Fatigue Lives of Laser-Cut Metals

Fatigue lives can be made to approach those attainable by traditional grinding methods.

Lewis Research Center, Cleveland, Ohio

It has been demonstrated that the combination of the removal of metal by lasers with methodology for balancing via the use of influence coefficients holds promise as a new approach to precise balancing of components of gas-turbine engines. However, to qualify laser balancing for gas turbines, a comparison must be made between the fatigue lives of rotors machined by a conventional manual grinding technique and those machined by lasers.

To make this comparison, fatigue-test specimens were prepared from four metallic alloys; and material was removed from these specimens by manual grinding, by an Nd:glass laser, and by an Nd:YAG laser. The results of fatigue tests of all of the specimens indicated a reduction of fatigue strengths of the laser-fired specimens below those of the ground specimens. However, there was a lesser reduction of fatigue strength, particularly at lower numbers of cycles, in the case of the Nd:YAG laser.

Laser machining holds promise for improved balancing of components of gas turbines. The use of Nd:YAG lasers together with techniques for careful finishing of the burn zone offers potential for fatigue life comparable to that attainable with traditional grinding methods.

This work was done by Michael R. Martin of Mechanical Technology Inc. for **Lewis Research Center**. *No further documentation is available. LEW-14682*

Stable and Oscillating Acoustic Levitation

Sample stability or instability is determined by levitating frequency.

NASA's Jet Propulsion Laboratory, Pasadena, California

The degree of oscillation of an acoustically levitated object along an axis of a levitation chamber can be controlled by varying the frequency of the acoustic driver for that axis above or below the frequency of the corresponding chamber resonance. The stabilization/oscillation technique can be applied in normal Earth gravity, or in the absence of gravity, to bring an object quickly to rest at a nominal levitation position or to make the object oscillate in a desired range about that position.

Typically, the problem is to control vertical oscillations about the equilibrium position in a gravitational field (see Figure 1). The restoring-force parameter (effective spring stiffness) for the oscillation varies with the acoustic pressure, the frequency, and the vertical position. Thus, the spring stiffness is modulated by the oscillation. As a further complication, the resonant frequency varies slightly with the position of the sample, and the finite time required to reach steady-state pressure in an acoustic resonator results in dephasing.

The combined effect of these phenomena during a number of cycles of the oscillation can be to pump energy into the oscillations (increasing the oscillation amplitude),

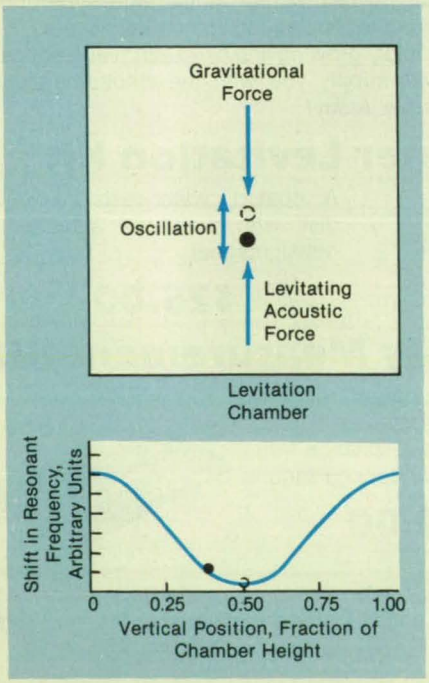


Figure 1. A **Levitated Object** oscillates vertically about a nominal or equilibrium position as though it were suspended on a spring. The chamber resonant frequency varies slightly with the vertical position of the sample.

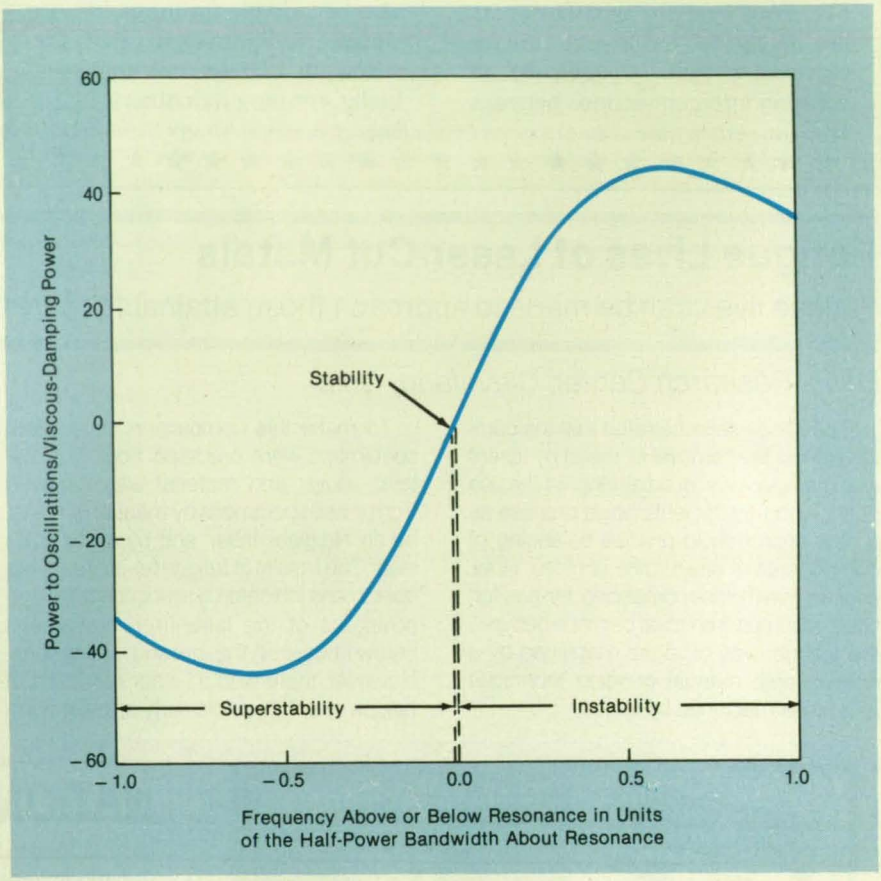


Figure 2. **Vertical Oscillations Grow or Are Damped** in a representative system at a rate determined by the frequency relative to the resonant frequency of the chamber. The parameters of the system are the following: normal Earth gravitation (980 cm/s^2), acoustic pressure 160 dB, relative bandwidth of resonance = one one-hundredth, and oscillation amplitude = one-tenth the height of the chamber.

to withdraw energy from the oscillations (decreasing the oscillation amplitude), or to do neither. If the effect is to contribute just enough energy to balance the energy lost to viscous drag, then the oscillation amplitude stays the same. If the effect is to withdraw energy, then it acts in concert with viscous drag to damp the oscillations quickly. If the effect is to add energy, then the oscillations grow.

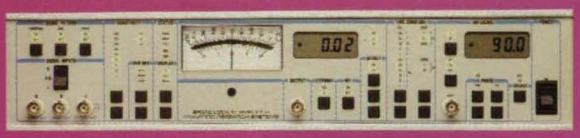
Calculations and experiments show that the acoustic field pumps energy into, does not exchange energy with, or withdraws energy from the oscillations when the levitating frequency is above, at, or below the resonant frequency of the chamber, respectively (see Figure 2). (Because of the viscous drag, the required levitating frequency for the onset of growth of oscillations is slightly above the resonant frequency.) If the actual levitating frequency is fixed at a value slightly above this onset frequency, the oscillations grow until the nonlinear competing effects raise the onset frequency to the actual levitating frequency.

This work was done by Martin B. Barmatz of Caltech and Steven L. Garrett of Naval Postgraduate School for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 16 on the TSP Request Card.*

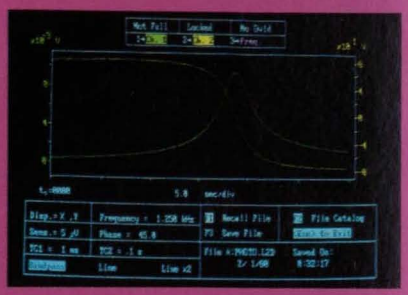
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-16896.

The Solutions...

Lock-In Amplifiers



RS232/GPIB



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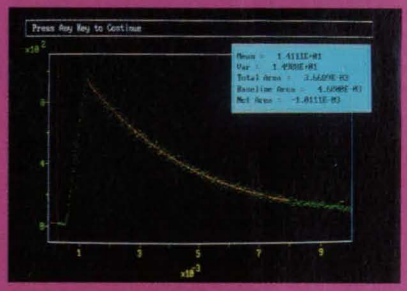
Photon Counters

RS232/GPIB



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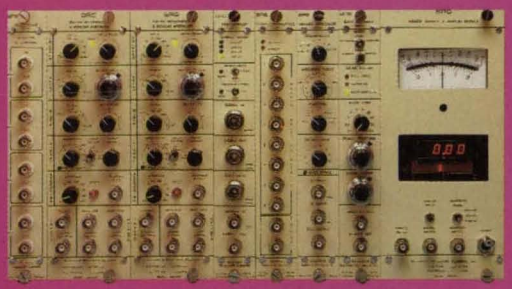
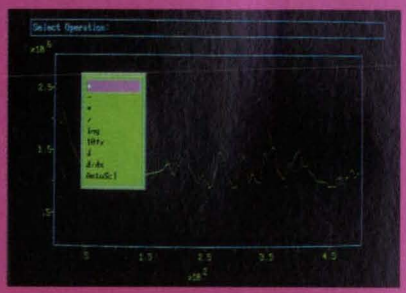


RS232/GPIB



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Dimpling Tools Would Form Fastener Neatly

A cup washer would be deformed to hold a screwhead.

Marshall Space Flight Center, Alabama

A proposed set of tools would neatly dimple a cup washer to prevent a screw from turning in its mounting hole. Two dimples are required: one leaning outward to grip a recess in the mounting hole and one leaning inward to grip a recess in the screwhead. The tools would not cause the cracks and tears that are often created when cup washers are dimpled by hammers and center punches. The tools would substitute a die-forming process for the hammer-and-center-punch process. The die-forming process would require less skill and would give results of greater quality and consistency.

The inward-leaning dimple would be formed first. As shown in Figure 1, the screw would be mounted on a plate and oriented with its recess facing a staking die. The screw and cup washer would be squeezed between the staking die and the die shoe, bending a portion of the cup washer into the recess in the screwhead.

The screw and cup washer would then be inserted in the mounting hole and oriented so that the first dimple faces away from the mounting-hole recess to be engaged. The forming tool in Figure 2 would be aligned approximately with the recess to be engaged, then forced between the cup washer and the screwhead to bend part of the cup washer outward. The shoulder on the holder of the forming tool would prevent insertion to an excessive depth.

This work was done by Michael D. Roberts and Donald R. Hendrickson of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29306.

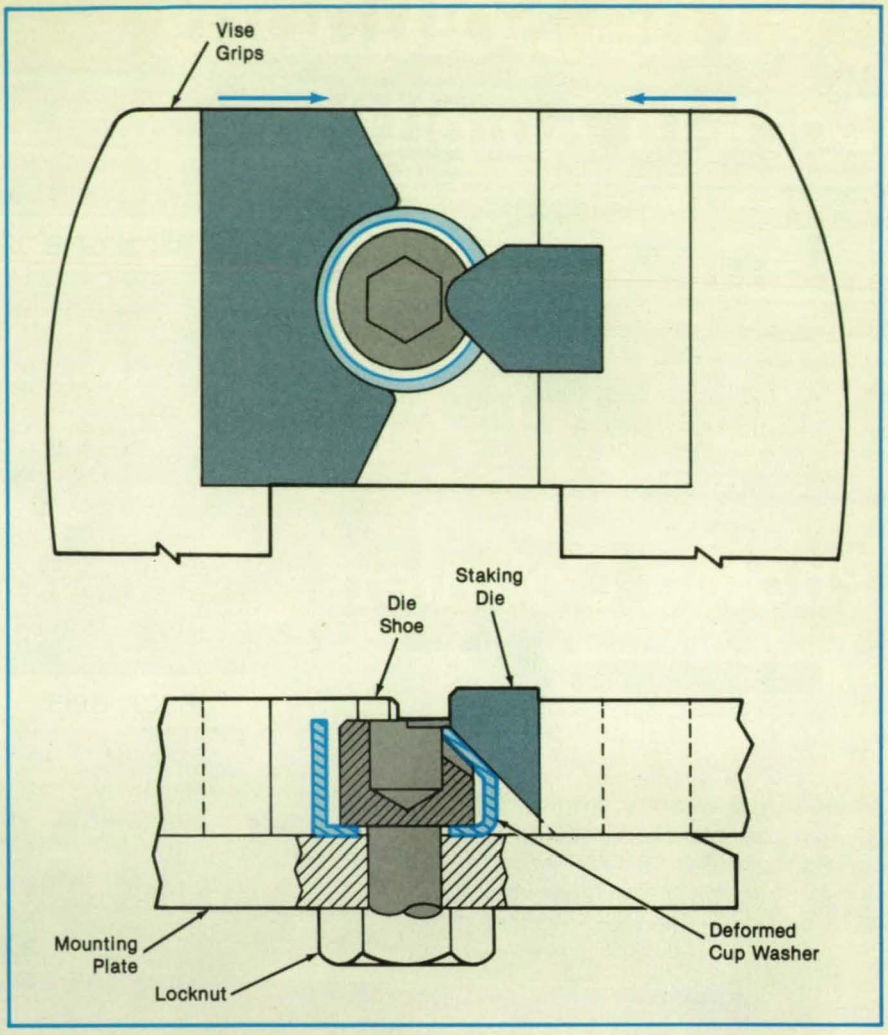


Figure 1. A **Staking Die** would form a dimple in the cup washer, causing the washer to grip the head of the screw.

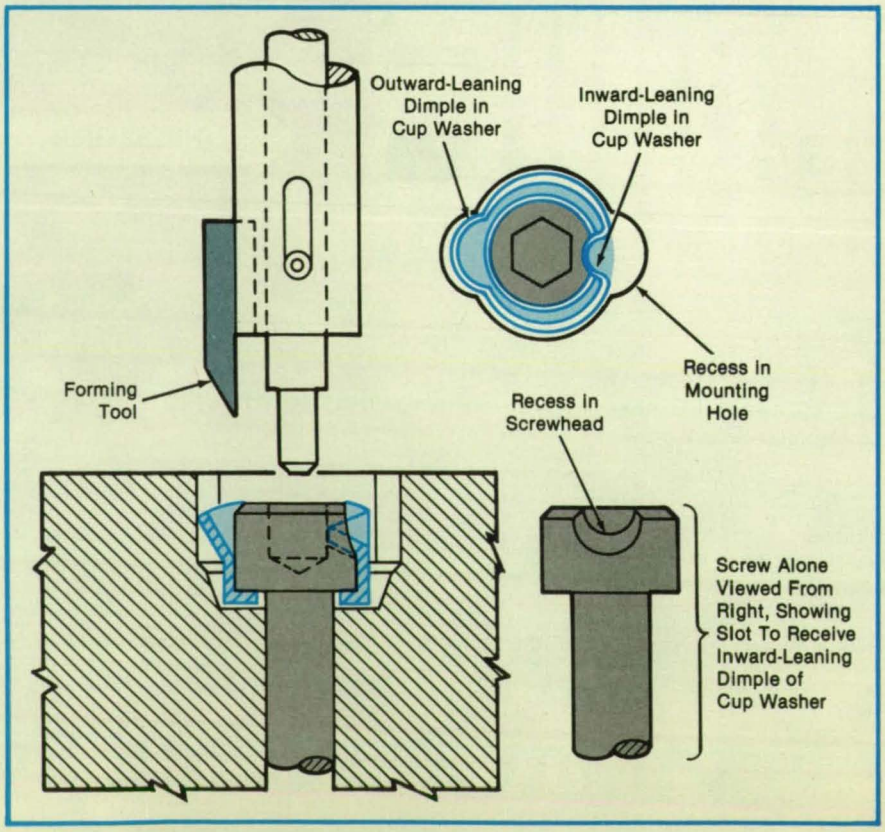


Figure 2. A **Forming Tool** would create another dimple in the cup washer, causing the washer to grip one of the recesses in the mounting hole. The screw would then be restrained against turning.

Vibrations Would Induce Flow in Molten Silicon

Flow patterns and velocities would be controlled to improve crystals.

NASA's Jet Propulsion Laboratory, Pasadena, California

According to a proposal, intense sound would be used to induce flow in molten silicon to increase the quality of crystals grown in the shallow-melt Czochralski process. In that process, the depth of the melt under the growing ingot is kept below the critical value for the onset of buoyancy-induced convection, to prevent the formation of inhomogeneities in the ingot. However, the flow of liquid in the region of growth is still uncontrolled.

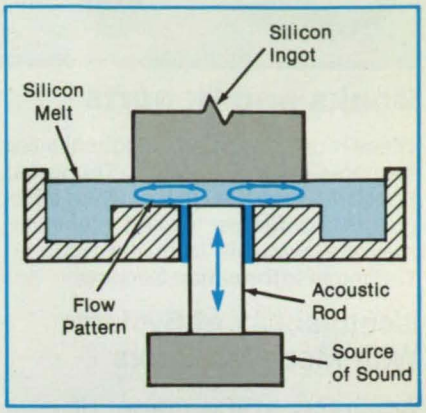
The insertion of an acoustic rod in the melt can cause acoustic streaming, which can be exploited to obtain a controlled, predictable flow of the nutrient melt. Another application of acoustic streaming is to counteract the effect of gravitation — an acoustic rod can create a circulation opposite that caused by gravitation (see figure).

The velocity of the flow depends on the intensity of the sound field. The acoustic-streaming pattern depends on the size and shape of the crucible or melt chamber, the type of acoustic excitation (whether standing-wave or traveling-wave), the boundary conditions, and the temperature gradient in the chamber.

The acoustic source can be a simple vibrating piston in the chamber wall. In that case, the acoustic flow would be along the axis of the source and away from the source, with countercurrents back to the source at a distance from the forward stream. If the source were positioned along the axis of a long tube, the liquid in the sound beam would flow away from the source and return along the wall of the tube. If the source were to excite an entire closed chamber into plane standing waves, the liquid flow would consist of clockwise and counterclockwise circular patterns that would repeat each half wavelength of the sound.

This work was done by M. B. Barmatz and A. D. Morrison of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 66 on the TSP Request Card.*

NPO-17087



A **Vibrating Rod** forces molten silicon to flow upward under the growing surface of a silicon ingot. The normal gravitationally induced convection would be in the opposite direction.

Mathematics and Information Sciences

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Identifiability of Systems With Modeling Errors

Advances in the theory of modeling errors are reported.

A recent paper is one in a series on errors in mathematical models of deterministic linear or weakly nonlinear systems. It extends the theoretical work described in "Structural Error and Identifiability in Mathematical Models" (NPO-16661) and "Near Identifiability of Dynamical Systems" (NPO-16785), both on page 77 of *NASA Tech Briefs*, Vol. 11, No. 1 (January 1987). The paper presents a concrete way of accounting for the difference in structure between a mathematical model and the physical process or system that it represents.

As used in the theory of mathematical modeling, "system identification" denotes the selection of a model structure, testing of the structure to insure the uniqueness of the values of its parameters (the identifiability test), and estimation of the parameters. The authors approach system identification by assuming, at the outset, that a model contains structural errors that may affect the identifiability of the model and the final values of the parameter estimates.

The modeling problem is formulated by including an additive error term in the differential equations for the state, inputs, and outputs of the system. After introducing several definitions regarding quantitative measures of near identifiability and the near equivalence of models or of a model and a process, the authors obtain mathematical conditions under which the difference between the outputs of the model and of the process remains within a desired bound in the presence of modeling errors. The theoretical development concludes with proofs of theorems on the conditions for identifiability and distinguishability in the presence of structural errors.

Because models never represent physical systems exactly, the concept of near equivalence and the quantitative measures of it lead to a more practical formulation of the identification problem. One consequence is that in future research on identifiability, it will not be necessary to assume that the process under study is a member of the class of models being investigated.

This work was done by Yadolah "Fred" Hadaegh of Caltech and George A. Bekey of the University of Southern California for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Identifiability of Systems With Modeling Error: A New Formulation," Circle 34 on the TSP Request Card.*
NPO-17064

Conceptual Spacecraft-Guidance Algorithm

The required weight of the spacecraft would be minimized.

A report describes a conceptual algorithm for the guidance of a spacecraft to be launched from the surface of Mars. The spacecraft is to carry a canister of specimens from the surface to another spacecraft in orbit about Mars; the second spacecraft is then to carry the canister back to Earth.

The optimal trajectory would comprise five phases. After a short vertical rise, the ascending spacecraft would turn to a short flight at fixed tilt. Next, the ascending spacecraft would perform a long closed-loop gravity turn to compensate for errors, followed by a long coast to reach the desired orbit. The rockets would then be fired to insert the ascending spacecraft into the orbit, ahead and above the orbiting spacecraft. Guided by optical sensors that view flashing lights on the newly ascended vehicle against the dark sky background, the orbiting vehicle would then maneuver to meet the ascended vehicle.

The closed-loop guidance would be implemented by the algorithm, which is based on numerical prediction/correction techniques. Although it would require more execution time than the analytic Powered Explicit Guidance algorithm used on the Space Shuttle, the conceptual algorithm has the advantage of being able to represent accurately many external forces that cannot be easily represented analytically. The mathematical modeling of the significant external forces eliminates the need for trajectory-dependent target biasing while resulting in an extremely accurate prediction of the trajectory. The aerodynamic drag is calculated with the help of an exponential model of the Martian atmosphere. The perturbations of the gravitational field caused by the oblateness of Mars, the unperturbed component of the gravitational field, and the spacecraft rocket thrust are also included in the model.

The conceptual algorithm was tested by a numerical simulation that included an analysis of the effects of various errors in the modeling of the specific impulses of the first- and second-stage rocket engines, the burning rate of the solid-fueled first stage, the aerodynamic drag, and the Martian atmosphere. The algorithm proved fast and accurate enough to satisfy the requirements. The approach to development of the algorithm is sufficiently general to be adaptable to prediction/correction algorithms for other spacecraft configurations.

This work was done by Bernell R. McCormick and James W. Compton of McDonnell Douglas Corp. for **Johnson Space Center**. *Further information may be found in the report, "Mars Sample Return Ascent Vehicle Conceptual Guidance Algorithm."*

Copies may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.
MSC-21286

★ ★ Technology Forecast ★ ★

Artificial Intelligence

"In coming years artificial intelligence will have a dramatic effect on space flight, especially in the areas of mission operation and spacecraft autonomy. Ames is now working with the Jet Propulsion Laboratory on the first version of hardware and software for a Mars Rover which will be heavily influenced by AI technology, increasing the vehicle's ability to plan, replan, and survey the Martian environment. In addition, knowledge-based expert systems will help automate the analysis of data captured by such a vehicle."

Dr. Peter Friedland,
Chief of the Artificial Intelligence Research Branch at NASA's Ames Center.

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MATLAB is an interactive system for scientific and engineering numeric computation. Problems and solutions are expressed just as they are written mathematically -- ***without traditional programming***. As a result, you can solve numerical problems in a fraction of the time required to write a program in Fortran, Basic, or C.

MATLAB has rapidly become an industry standard for engineering and scientific research. Its unique interactive interface, algorithmic foundation, easy extensibility, and speed make MATLAB the software system of choice for ***high productivity and high creativity*** research.

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• singular value decomposition, ***and more***

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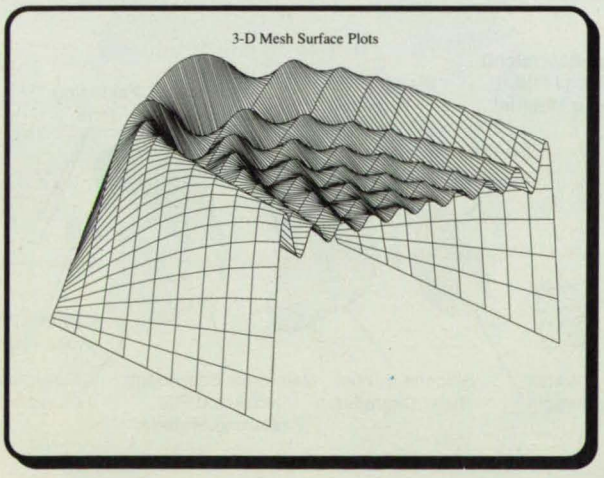

Computers

- ✓PC and AT Compatibles
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- ✓Macintosh
- ✓Sun Workstations
- ✓Apollo Workstations
- ✓VAX/VMS and Unix
- ✓Other Computers

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Benchmarks (20 MHz 386-based PC)

20x20 matrix multiply	0.05s
20x20 inverse	0.11s
20x20 eigenvalues	0.6s
1024 point FFT	0.16s

MATLAB is the teaching and research system chosen by Computer Science, Engineering, and Mathematics departments at most top universities. These creative researchers use MATLAB to design algorithms that are at the cutting edge of technology. As a result, you are assured of an exciting future of new developments, implemented with the speed, power, and flexibility that have made MATLAB a standard.

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NASA 12-88

Circle Reader Action No. 503

Experimenting With Baroreceptor Reflexes

The carotid arteries are stimulated by pressure or suction on the neck.

Lyndon B. Johnson Space Center, Houston, Texas

A chamber strapped to the neck of a human subject applies pressure or suction of controlled magnitude and duration to the carotid arteries. The chamber, called a Baro-Cuff, was developed to study the blood-pressure-reflex responses of astronauts in outer space. It may also be useful for terrestrial studies of patients with congestive heart failure, chronic diabetes mellitus, and other conditions in which the blood-pressure-reflex controls behave abnormally.

The chamber stimulates baroreceptors — the body's blood-pressure sensors — in the carotid arteries. Meanwhile, instruments measure and display the pressure in the chamber and the subject's electrocardiogram and respiration. Researchers can thus observe responses to a variety of stimulus patterns.

The Baro-Cuff is molded uniquely to fit the front of the subject's neck so that it provides a seal for both positive and negative pressures. The seal leaks so little that a bellows can be used instead of a pump to change the pressure in the chamber (see figure). The bellows, driven by a stepping motor, is smaller and quieter than a pump and uses less power. The bellows sets the pressure in the range from −65 to +40 mm of mercury (−8.7 to +5.3 kPa) — within the limits of comfort of most human subjects.

A microprocessor chip controls the stepping motor and collects the data. Erasable, programmable, read-only memory chips store custom software for the microprocessor. The software can be modified as necessary to change the timing, amplitude, polarity, rate of change, intensity, and duration of pressure. The system can change pressure at a rate fast enough to stimulate rate-sensitive receptors — that is, above about 300 mm of mercury (40 kPa) per second.

In the outer-space application, the subject conducts the experiments. The subject sets thresholds with the aid of cursors on an electrocardiogram and respiration signals displayed on an oscilloscope. After establishing a normal respiratory cadence, the subject presses a button on a keypad to start an experiment. The subject then breathes two more times and holds his or her breath for 4 s.

At this point, the pressure in the chamber is increased. The microprocessor adjusts the bellows during the next four heartbeats to keep the pressure in the chamber close to 40 mm of mercury (5.3 kPa). After this interval, successive *R* waves of the electrocardiogram trigger reductions in pressure to 25, 10, −5, −20, −35, −50, and −65 mm of mercury (3.3, 1.3, −0.1, −2.7, −4.7, −6.7, and −8.7 kPa, respectively). After the last decrement, the system returns the pressure to the ambient level for two heartbeats, then sounds an alarm to tell the subject to breathe again.

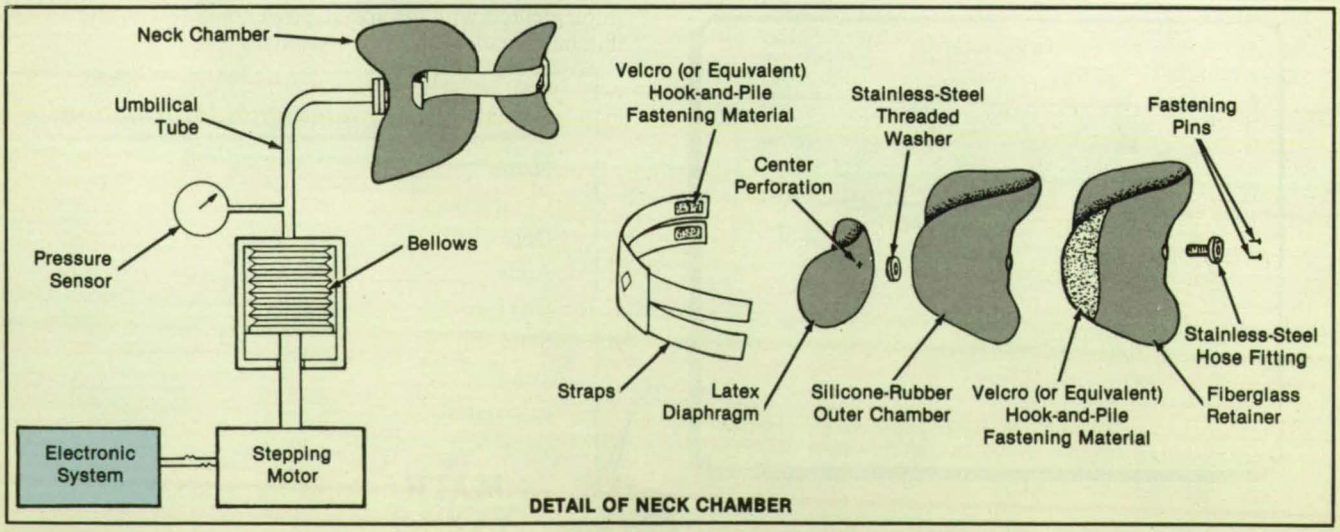
The sequence is repeated seven times to complete a session. The subject measures his or her blood pressure manually before the first sequence and after the third and seventh sequences and keys the values into the microprocessor. At the end of a session, the system displays average *R-R* intervals and chamber pressures for each step.

This work was done by Dwain L. Eckberg of Virginia Commonwealth University and Ross L. Goble of Engineering Development Laboratory for **Johnson Space Center**. *For further information, Circle 89 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Edward Ansell
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1207 East California Boulevard
Pasadena, CA 91125

Refer to MSC-21388, volume and number of this NASA Tech Briefs *issue, and the page number.*



The **Baro-Cuff** is a silicone-rubber chamber that fits on the front of the subject's neck. The electronic system, stepping motor, bellows, and umbilical tube furnish controlled pressure to the chamber. The pressure sensor provides feedback to the microprocessor in the electronic system.

Measuring Time-Averaged Blood Pressure

An instrument removes the dynamic component so that only the average component remains.

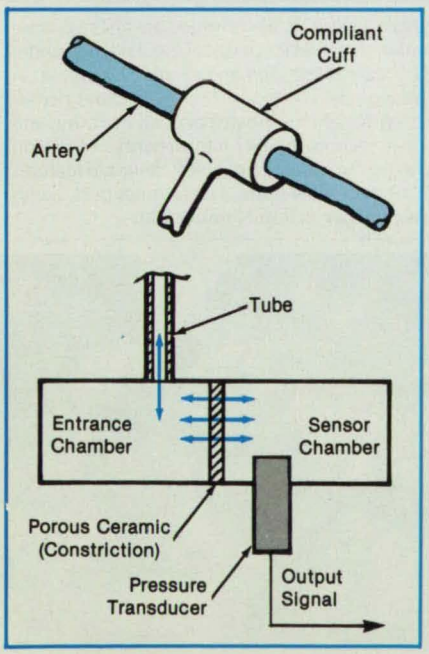
Goddard Space Flight Center, Greenbelt, Maryland

A device measures the time-averaged (static) component of absolute blood pressure in an artery instead of the usual diastolic and systolic extremes of pressure created by the heart's pumping action. The device includes a compliant cuff around the artery and an external monitoring unit.

The cuff is connected to the monitoring unit through a flexible tube. The cuff, tube, and monitoring unit are filled with an isotonic fluid, which transmits the pressure from the artery to the monitoring unit.

A ceramic constriction divides the monitoring unit into two chambers (see figure). The constriction filters out the dynamic component of pressure in the entry chamber so that only the time-averaged pressure component is present in the sensor chamber. An electrical transducer in the sensor chamber produces a signal indicative of the pressure.

This work was done by Neil S. Rothman of The Johns Hopkins University, Applied Physics Laboratory. No further documentation is available. GSC-13044



The **Ceramic Constriction in the Monitoring Unit** suppresses the ebb and flow of pressure-transmitting fluid in the sensor chamber. The transducer thus measures only the static component of the blood pressure.

★★★★★★★★ **Technology Forecast** ★★★★★★★★

Flow Cytometry

"We're working with the American Cancer Society on a way to improve laboratory identification and monitoring of cancer cells through use of a Fourier transform spectrometer. Present flow cytometry instruments are very large, use a lot of power, and require well-trained operators who dedicate long hours on the job. The instrument we're developing would change all that. It could support biomedical experiments aboard Space Station with a minimum amount of crew time, while also providing an efficient way to evaluate changes in cancer cells resulting from chemotherapy or bone marrow transplants. We expect to develop a prototype cytometer within a year. Applications to cancer cell analysis are about four years down the road."

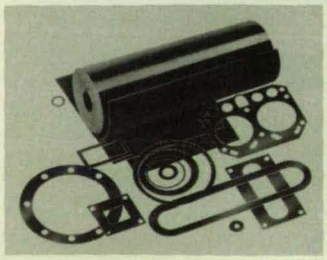
Dr. Gerald Taylor, Science Manager for the Space Station Biology Project at NASA's Johnson Space Center.

★★★★★★★★★★★★★★★★★★★★★★★★

New on the Market

A preformatted 5¼ inch **floppy disk** for IBM PCs, XTs, and compatible computers is now available from BASF Corp. Information Systems, Bedford, MA. Packed in boxes of ten, the double-sided, double-density diskettes are shipped ready for immediate use and are certified 100 percent error free. They are preformatted for MS-DOS versions 2.0 and higher. **Circle Reader Action Number 800.**

The Sony Corporation of America, Park Ridge, NJ, has introduced a family of **rewritable optical disk drives,** controllers, and media for OEMs, VARs, distributors, systems integrators, and workstation manufacturers. The Model SMO-S501 self-contained optical disk drive subsystem and the Model SMO-D501 optical disk drive device allow users to write, read, and erase large amounts of information. The drives provide a sustained transfer data rate of 7.40 megabits per second and can access up to 3M bytes of data in less than 40 msec. A SCSI host controller and power supply connect the optical disk drive subsystem to workstations, network fileservers, and PCs. **Circle Reader Action Number 778.**



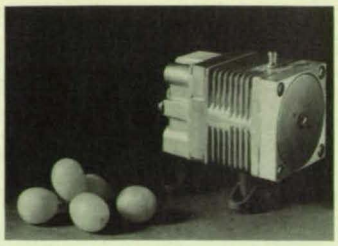
Dyflex® **Graphite** from the Dylon Graphite Company, Berea, OH, can withstand temperature extremes from cryogenic to 450°C in air and 3000°C in a non-oxidizing atmosphere. The material features high thermal and electrical conductivity and can be cut with a knife or scissors into a variety of shapes. Its uses include lining bearings, molds, troughs, dies, hot tops crucibles, and other industrial parts. Placing the graphite sheeting between layers of parts prevents sticking during extrusion and firing of ceramics and metals. **Circle Reader Action Number 782.**

LaserRays software from Lazerus, Berkeley, CA, enables users of PC, XT, AT, or 386-class computers to create graphics with 32-bit floating point precision. The **ray-tracing software** allows modeling of two- or three-dimensional scenes with accurate reflections, transparency, shadows, and texture. Objects can be rotated and translated in each of the three axis directions and then scaled. LaserRays is supplied with sample images and online user documentation. **Circle Reader Action Number 790.**

A new **epoxy formula** developed by Theramic Engineering Inc., Miami, FL, offers thermal resistance to 499°C. The epoxy bonds well to metals, ceramics, plastics, and glass, and features excellent corrosion resistance and dielectric properties. Applications include potting, sealing, casting, and coating of motors, pumps, instruments, and appliances. **Circle Reader Action Number 786.**

TECPLOT, an interactive **program for plotting** contour lines, color-flooded contours, vector fields, streamlines, and X-Y plots has been developed by Amtec Engineering Inc., Bellevue, WA. The program enables users to quickly create and display plots with multiple datasets and windows. The plotting process can be interrupted for alterations in positioning, color, size, and labeling. Versions are now available for IBM PC/XT/AT computers and Apollo 3000/4000 workstations. **Circle Reader Action Number 796.**

Chromatics Inc., Tucker, GA, has introduced a new **color workstation** targeted for the high-performance graphics market. The CX2000 workstation integrates Chromatics' "Le Mans" Colorgraphic Display System with a CPU, UNIX, or VRTX 32 real-time operating system and up to 600 megabytes of hard disk storage. It can draw more than one million two-dimensional vectors or 160,000 three-dimensional vectors per second. Potential applications include mapping, simulation, animation, medical imaging, energy management, and signal processing. **Circle Reader Action Number 792.**



A new **micro air compressor/vacuum pump** from Medo USA Inc., Wood Dale, IL, features a powerful linear motor with a free-piston as its only moving part. The sparkless unit uses only 14 watts continuously and requires no oil. Applications include robotic, medical, printing, and industrial systems. **Circle Reader Action Number 784.**

Microware Systems Corp., Des Moines, IA, has released OS-9/PC-Bridge, a PC-hosted **software development system** that connects PC-DOS to OS-9—the world's most powerful real-time operating system. OS-9 offers popular features of UNIX, a sophisticated set of development tools, plus support for each class of I/O device—all managed by a real-time kernal. PCBridge links to the OS-9 target system via high-speed serial line, and includes a C Language development environment integrated with a menu-driven user interface. **Circle Reader Action Number 788.**

The Model 4221 **Digital Temperature Indicator** from Instrulab Inc., Dayton, OH, can be digitally programmed without using calibration equipment. To match a specific sensor, the operator simply enters the calibration constants supplied by the sensor manufacturer into the instrument's memory. Readout is provided in Celcius and Fahrenheit with 0.001°C resolution and 0.001°C accuracy. **Circle Reader Action Number 794.**

Silicon Graphics Inc., Mountain View, CA, has unveiled the first real-time, **three-dimensional workstation** designed for personal use. Priced at under $16,000, the Personal IRIS™ can be installed and running a program in twenty minutes. The workstation delivers ten million instructions per second of CPU performance, with eight megabytes of main memory, and renders 59,000 polygons per second. It links into networks of Silicon Graphics, IBM, DEC, or Cray systems and mainframes. Standard features include Ethernet with TCP/IP, two serial ports, a Centronics port, audio ports, and a VME slot. **Circle Reader Action Number 780.**

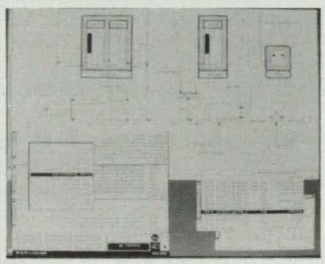
The 3M Company's Ceramic Materials Department has created a **fire-retardant additive** that expands up to 20 times to cut off oxygen and block the spread of fire. Expantrol™ Granules can be added to carpets, paints, roofing, plastic, rubber, and elastomers. The nonsoluble particles feature a high activation temperature and are 100 percent inorganic and environmentally stable. **Circle Reader Action Number 798.**

New on the Market

The Lobster BR-100M, a cordless blind **riveting tool** from SB Industries, St. Louis, MO, is suited for a variety of on-site construction applications. The lightweight tool has a 3/16 inch rivet capacity and comes equipped with a two-speed, gear-driven motor that supplies more than 1700 pounds of traction power. A battery and charger, four nosepieces, and a carrying case are included with the riveting tool.
Circle Reader Action Number 768.

An advanced clad metal **shielding material** developed by Texas Instruments' Materials and Controls Group features high attenuation over a broad frequency range (DC to GHz) and is effective in a variety of field strengths. The material, called TI-SHIELD, consists of three layers of foil with a ferromagnetic alloy core metallurgically bonded to outer layers of pure copper. The copper provides conductive reflection for high-impedance waves while the ferromagnetic alloy offers magnetic reflection for low-impedance waves—a combination that results in high energy absorption for minimum field penetration. TI-SHIELD is solderable and easily formed into enclosures or retrofit to walls.
Circle Reader Action Number 766.

Digital Publications Inc., Norcross, GA, has introduced **PC Yellow Pages**, a series of business directories for PC- and MS-DOS users. The software program features a compilation of 10,000 businesses nationwide with toll-free telephone numbers, and 5,000 businesses in the user's local area. The listings are accessible by either company name or type of business, with full addresses provided for local firms. The program includes automatic phone dialing, label printing, and exporting capabilities. Available on 5¼ inch diskettes, the PC Yellow Pages costs $99.99, with annual updates offered at $7.00 each.
Circle Reader Action Number 770.



Foresight, a graphics-based **modeling tool** from Athena Systems Inc., Sunnyvale, CA, enables engineers to simulate real-time embedded system designs. Users can build computer-generated prototypes that include the logic and timing behavior of the proposed system. Various test cases can then be processed by the simulator, allowing the engineer to view the data flow and outputs as they would occur in the final system. Foresight software presently runs on Sun workstations under UNIX. In 1989, support will expand to DEC VAXstations.
Circle Reader Action Number 764.

Saphikon Inc., Milford, NH, has developed high-temperature **sapphire fibers** for aerospace and advanced composite manufacturing. Saphikon's fibers exhibit a mean tensile strength of 450,000 psi at room temperature, can withstand 2,000°C temperatures, and feature a high elasticity modulus. The sapphire fiber is the strongest material in oxidizing or other reactive environments at temperatures up to 1400°C, according to the manufacturer, and is compatible with a variety of matrix materials.
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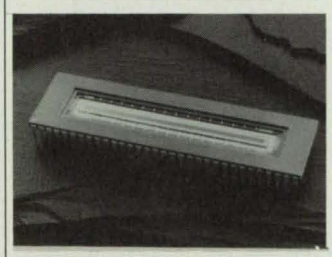
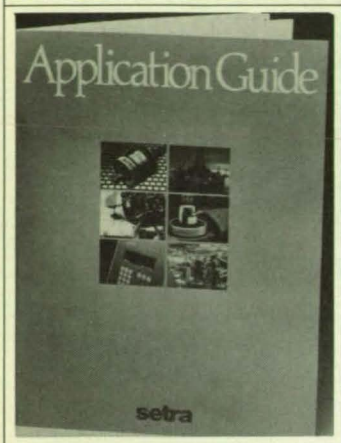
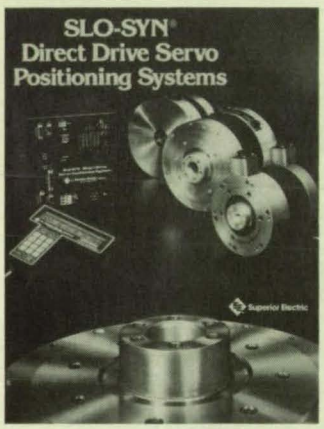


EG&G Reticon, Sunnyvale, CA, has created a new **CCD imager** for high-speed line scan inspection in very low light. The Reticon model RL2048J provides 2048 resolution elements at more than 60,000 scans per second. This array cuts lighting and production costs for document scanning, printed circuit board inspection, and other production line inspection tasks.
Circle Reader Action Number 762.

New Literature



Setra Systems Inc., Acton, MA, is offering a **free application guide** designed to help engineers select pressure transducers for HVAC/R, industrial process control, and OEM environments. The eight page guide provides a selection chart for transducers and two-wire transmitters; a data sheet on media compatibility, pressure ranges, accuracy, and thermal effects; and a pressure conversion chart.
Circle Reader Action Number 716.



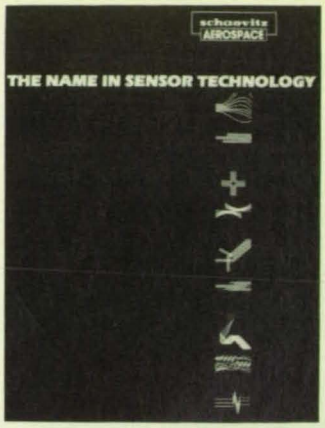
The Superior Electric Company's new catalog describes gearless Slo-Syn® **Direct Drive Servo Positioning Systems**, which feature a unique cogging-free and brushless high-torque motor design. The motors' low inertia make them suited for situations requiring fast response, or for accomodating wide load variations on the motor shaft. Applications include robotics, process controls, actuators, machine tools, and textile equipment.
Circle Reader Action Number 726.

The **PCB-CAD Buyer's Guide** from Personal CAD Systems Inc., San Jose, CA, provides guidelines for selecting printed circuit board design software. Available free of charge, the 24 page booklet reviews CAD system features, outlines typical payback calculations, and presents criteria for a system lifecycle analysis.
Circle Reader Action Number 704.

The **supercomputing capabilities of the IBM 3090** for the defense, energy, and transportation industries are described in a free brochure from the IBM Corporation, White Plains, NY. Applications to structural analysis, fluid dynamics, computational chemistry, quantitative analysis, and mathematical techniques are highlighted with color illustrations. Designed for scientists and engineers, the 3090 with Vector Facility provides scalar, vector, and parallel processing of complex computations.
Circle Reader Action Number 714.

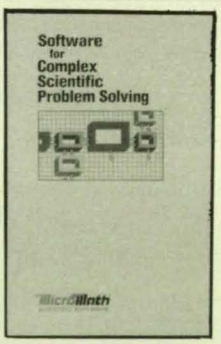
A free full-color catalog from Jensen Tools Inc., Phoenix, AZ, illustrates new service kits and a broad array of **tools and test equipment** for electronic and electro-mechanical maintenance. Included are hand and power tools in inch and metric sizes, lighting aids, soldering supplies, equipment cases and shipping containers, and new wire and cable service products.
Circle Reader Action Number 720.

A Z Industries Inc., Temecula, CA, has published a **magnetic instrumentation brochure** featuring such products as a hand-held, battery-powered gaussmeter, a north-south pole indicator, a one-inch-square magnetic imager, and a highly sensitive magnetic field dosimeter. The free brochure also describes "Footprints of Magnetism," a large-scale magnetic imager developed for schools, museums, and other educational settings to illustrate magnetic fields. The unit contains four square feet of viewing area and comes with a set of eight demonstration magnets.
Circle Reader Action Number 722.



A free brochure from Schaevitz, Pennsuaken, NJ, outlines aerospace and military applications of Schaevitz **sensor systems**. Solutions to measurement of acceleration, pressure, and displacement in satellites, submarines, weapon and fuel systems, and aircraft control systems are illustrated. The color brochure highlights successful sensor applications, including the Lear Jet, F-14, AH64 helicopter, and Trident missile.
Circle Reader Action Number 724.

A new report from Booz Allen & Hamilton Inc., New York, describes **Japan's emerging aerospace industry** and analyzes the implications for U.S. aerospace firms. The Japanese aerospace industry will grow from $7 billion today to $30 billion in constant dollars by the year 2000, according to the report, which cites parallels to development of other key Japanese industries, including steel, consumer electronics, and automobiles. The report also discusses strategies for U.S. competitiveness in this increasingly global aerospace market.
Circle Reader Action Number 710.



"Software for Complex Scientific Problem Solving," a new catalog from MicroMath® Scientific Software, Salt Lake City, UT, illustrates the company's line of **software products for research applications**. These include: GRAPH, a program for x-y plotting and data transformation; MINSQ, a powerful model development tool; RSTRIP, a program for polyexponential curve stripping and parameter estimation; and LAPLACE, a software package that simplifies the simulation of complex physical/chemical systems.
Circle Reader Action Number 712.

The 1989 edition of the **Space Station Directory and Program Guide** is now available from Pasha Publications Inc., Arlington, VA. The guide describes the evolution of the Space Station program, highlights the four major work packages and contractor teams, and analyzes commercial uses of the orbiting platform. It also includes an annotated bibliography of NASA reports on Space Station development plans, a glossary of technical terms, and numerous diagrams, pictures, and charts.
Circle Reader Action Number 706.

Aerotech's new **Motion Control Product Guide** describes the company's line of motor-driven linear and rotary positioning stages, servo motors and amplifiers, DYNACRON microstepping translators and stepping motors, and UNIDEX™ motion control systems. The 148 page catalog includes graphs, photos, specification tables, and a detailed applications section.
Circle Reader Action Number 718.

The **World Report on Advanced Ceramics**, published by Technical Insights Inc., Fort Lee, NJ, analyses both the technical and commercial significance of new research on ceramic materials. Among the breakthroughs described are a ceramic diesel engine, a high-strength ceramic/metal bonding technique, and two near-net-shape ceramic fabrication processes. The report also covers patent grants, partnerships, and licensing arrangements.
Circle Reader Action Number 708.

The new 1988 Government Computer Source Code Directory from Source Translation & Optimization, Belmont, MA, lists **9,000 computer programs available from the U.S. government**. The directory features 75 categories, including aerospace, defense, energy, engineering, management, mathematics, and science. Programs are available on diskettes or tape, and work on all platforms, from PCs to mainframes. Documentation is available for user guides and training. Government software costs about 10 cents per line of code, as opposed to 95 cents per line for commercial programs.
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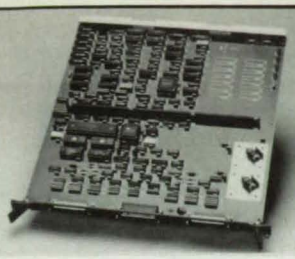

The new V/SMD 4400 Phoenix SMD disk controller from Interphase is the highest performing controller for Sun Microsystems workstations and file servers. It provides full boot support for Sun 2 and Sun 3/1XX, Sun 3/2XX and Sun 4/2XX models with OS3.X and OS4.0 and supports as many as four SMD or SMD-E drives with data transfer rates to 24 Mb/s. Intelligent multi-track caching capabilities and the speed of BUSpacket Interface improve throughput for the UNIX file system for both large and small transactions.

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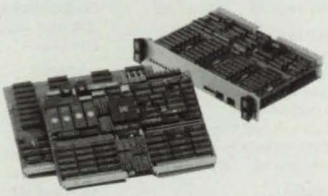

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Catalog Describes Scientific-Atlanta's Telemetry, Tracking and Control Systems Products

Scientific-Atlanta, Inc., has published a catalog which describes its line of land-based and shipboard telemetry, tracking and control systems. The catalog provides descriptions and specifications for the company's tracking pedestals, control systems, antennas and earth terminals as well as tracking system formulas and definitions.

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Subject Index Of All 1988 Tech Briefs

The following pages contain a cross-referenced index of all technical briefs published in NASA Tech Briefs during 1988 (Volume12). The blue listings refer to briefs appearing in this issue. You can receive more information on these briefs by requesting the Technical Support Package (TSP) referenced at the end of the full-length article. For information on briefs featured in previous issues of Volume 12, call or write to NASA's Scientific and Technical Information Facility (see page 20).

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